ASPECTS OF ULTRADIAN RHYTHMS IN MAN

by

Peretz Lavie

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA
1974

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. Wilse B. Webb who supervised the research described in this dissertation, and to the members of the supervisory committee: Drs. C. Michael Levy, Mark C. Yang, Edward P. Horne, Robert L. Isaacson and Frederick A. King. Special thanks go to Drs. C. Michael Levy for the use of his laboratory, and Edward P. Horne for the use of the beta movement apparatus.

Special thanks also go to David Sutter, without whose assistance this work would have been impossible, and to his wife, Lena Lavie, for her sacrifice, patience and understanding during the last three years.

And last but not least, the author wishes to express his thanks to the 34 un-paid volunteers, who dedicated more than 50 experimental nights and 400 experimental hours to this research. Their cooperation is deeply appreciated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

ASPECTS OF ULTRADIAN RHYTHMS IN MAN

By

Peretz Lavie

June, 1974

Chairman: Wilse B. Webb
Major Department: Psychology

Three related experiments were conducted in order: (1) to explore the relationship between the REM-NONREM cycle and the waking cycle in the perception of the spiral after-effect (SAE); (2) to assess the influence of interruptions of REM and NONREM sleep on the perception of the beta movement (βM); (3) and to compare the possible cyclicity in perception of the βM during waking with the cyclicity in the perception of the SAE.

The results of the first study revealed that Ss awakened from the beginning or middle of NONREM sleep reached a first peak in the perception of the SAE earlier than when awakened from the beginning or the middle of REM sleep. In addition, Ss whose median awakening was 6:10 AM reached peaks in perception earlier than Ss whose median awakening time was 3:12 AM. The results were interpreted as supporting the hypothesis that the waking cycle, as indicated in the perception

of the SAE, is continuous with the REM-NONREM cycle, and that both cycles reflect an underlying ultradian biorhythm.

In the second study, Ss demonstrated significantly wider ranges of the βM when awakened from REM sleep than NONREM sleep; the REM awakening ranges were even greater than the test results prior to sleep. The results were interpreted to support the assumption that the cortical activities of REM sleep penetrate into waking, and thus modify perceptual processes.

The results of the third experiment indicated that Ss perceiving the SAE every 5 min, and the βM every 20 min, for 8 hours, demonstrated significant tendencies toward alternating periods of long SAE durations and wide βM ranges, and periods of short SAE durations and narrow βM ranges, approximately every 70 to 150 min. Furthermore, suggestive evidence was found to support the results of Experiment 1. Subjects awakened from REM sleep revealed perceptual cycles out of phase with respect to the perceptual cycles of Ss awakened from NONREM sleep. The results were interpreted to support the accumulated data for the existence of a waking ultradian biorhythm which is synchronized with that of the REM-NONREM cycle.

I INTRODUCTION

Evidence for the existence of a short term periodicity in the activity of the central nervous system can be traced back to the beginning of the century. Wada (1922) observed a 40-45 min activity cycle in infants, which she associated with periodic gastric contractions. Wada also noted similar gastric episodes in adults, both during the waking and sleep states, but at intervals of one and a half to two hours. Denisova and Fingurin (1926) described a 50 min respiratory cycle in infants during sleep, consisting of alternating fast and slow breathing. Regellsberger (1942) plotted changes in CO_2 content of alveolar air, and electric chin resistance during sleep, and obtained a scalloped curve with 55 to 120 min intervals between peaks. Similar periodic alternations between regular and irregular respiration periods during sleep were reported by Magnussen (1944); the regular and irregular periods were 38-52 min and 40-60 min, respectively. Olmeyer et al. (1944) anticipated the sleep era by reporting an 85 min penile erection cycle during sleep.

Until the sixties these findings were considered, at the most, as anecdotal data, or as noise in the results, and no attempt was made to explore further the possibility of the

existence of an ultradian rhythm in the functioning of the nervous system. The discovery of the REM-NONREM cycle by Aserinsky and Kleitman (1953) signaled the turning point in the understanding of the sleep process, and paved the way to the acceptance of the ultradian notion.

Kleitman (1961), relying only on shreds of evidence, speculated on the existence of short term periodicity in the functioning of the nervous system, for which he coined the name: Basic Rest-Activity Cycle (BRAC). According to Kleitman, this cycle originates as a primitive sleep and waking cycle which is adjusted to the organism's nutritional needs, and is essentially a gastric cycle mediated by humoral agents or hunger contractions. Advanced types of sleep and wakefulness develop as the organism matures, and the basic periodicity appears in the alternation between REM sleep and NONREM sleep. Besides its manifestation in the REM-NONREM cycle, Kleitman suggested that the Basic Rest-Activity Cycle may also manifest itself in the (matured) wakefulness phase as recurrent fluctuations in alertness. Kleitman's theory has only lately been confirmed by research, although he persistently continued to present it (1963, 1969, 1970, 1973).

Evidence for the existence of the approximate 90 min periodicity during the waking state has accumulated in the last decade, and can be divided into two categories: direct evidence showing the existence of "waking" ultradian[1] cycles

---

1. Ultra (shorter) + dies (day), or "shorter than a day." (Halberg, 1967).

similar to the 90 min sleep cycle, and indirect evidence showing "carry over" effects from a particular sleep phase into the immediate waking state; these effects resemble the characteristics of the previous sleep stage.

Indirect Evidence

The first researchers to show differential effect of awakening from REM sleep and NONREM sleep were Fiss et al. (1966), who reported that Ss gave more vivid and longer responses to the Thematic Apperception Test (TAT) when awakened from REM sleep than from NONREM sleep. Broughton (1968), discussing sleep disorders and their relation to the different stages of sleep, described an experiment in which visually evoked responses showed different characteristics when recorded following awakening from REM sleep and NONREM sleep. Following 25% of the awakenings from NONREM sleep, the visually evoked responses contained components apparently typical of slwo-wave, sleep-type EEG, despite the return of EEG patterns characteristic of the waking state. Even when there was no such electrocortical carry-over, the visually evoked potentials regularly showed decreased amplitudes and increased latencies of the later components. Following awakening from REM sleep, the visually evoked responses were essentially those of the pre-sleep wakefulness. No changes similar to those found for Ss awakened from NONREM sleep were found. Moreover, Broughton also suggested that differences in the awakening processes might be responsible for the

occurrence of part of the sleep disorders which involved automatic behavior like sleep walking, nightmares, bed wetting, etc. Feltin and Broughton (1968) reported that Ss awakened from REM sleep responded more quickly and with fewer "overshots" to white stroboscopic flashes, which appeared randomly with blue stroboscopic flashes, than when awakened from NONREM sleep.

Berger and Scott (1971) reported that binocular depth perception was more accurate at the termination of REM sleep than at the onset; their report attributed the impairment in the binocular depth perception to degradation in oculomotor coordination during NONREM sleep. These investigators stated that the function of REM sleep is to innervate the oculomotor system and thereby maintain facilitation of the coordinated eye movements during sleep. In a similar vein, Berger and Walker (1972) reported that ocular imbalances at the onset of REM sleep were significantly greater in magnitude and number than those at the end of REM sleep. They interpreted their results as supporting the oculomotor innervation hypothesis as the function of REM sleep.

Differential effects of the awakening from the two phases of sleep on the perception of the spiral after-effect were reported by Lavie and Giora (1973) and Lavie (1974). In the first study, subjects awakened from the beginning of REM sleep displayed longer durations of the illusion than those awakened from NONREM sleep (stage 4). Lavie (1974) confirmed these

results and showed that awakening from stage 2, 5 min after the end of REM sleep, also produced shorter illusions than awakening from the beginning of REM sleep. This difference was noticeable for a period of at least 15 min following the awakening.

Direct Evidence

Studies designed to explore directly the possibility of the existence of short term behavioral or physiological rhythms during the waking state were not conducted until six years after Kleitman suggested his theory. Friedman and Fisher (1967), assuming that the REM-NONREM cycle is a "cyclic waxing and waning of instinctual drive activity" which continues as a background factor during the day, tested the oral activity of isolated Ss for 6 hours. They found cyclic oral activity with a mean of 96 min and later Oswald et al. (1970) confirmed these results. Friedman also described orality cycles in schizophrenics (1968), and in obese patients (1972).

The hypothesized cyclicity in the functioning of the nervous system implied a resultant cyclicity in performance, particularly in the performance of tasks requiring high levels of arousability and attention. Globus et al. (1971) tested subjects on a continuous signal detection task and obtained equivocal evidence supporting an approximate 100 min ultradian rhythm in performance. In another study, Globus et al. (1973) correlated Ss' activity, as measured by telemetry, with sinusoids of different frequencies, and reported some relatively higher correlation coefficients for frequencies around

100 min. Frazier et al. (1971) observed the existence of a rhythm on the order of 22.5 cycles per day in the performance of similar tasks. Kripke (1972), in an extensive study, looked for periodic oscillations in various behavioral and physiological measurements during a long period of partial sensory deprivation. Analyzing the data, he observed significantly more cycles within the range 70 to 150 min, which was defined by him as the "ultradian range," than in the rest of the temporal spectrum. The most noticeable rhythms were observed in the EEG delta band amplitude and certain other EEG frequencies, and in lever presses for water. More recently, Kripke and Sonnenshein (1973) reported that Ss isolated for 10 hours and required to write a summary of their thoughts every 5 min, showed a 90 min cycle in the fantasy rates of their stories.

Some of the most convincing evidence for the existence of an ultradian rhythm in the functioning of the nervous system was given by Sterman (1972). He reported an intrauterian fetal activity cycle with a periodicity identical to the infant REM-NONREM cycle. The continuation of the cycle into the waking state was suggested by its clear manifestation in fetal activity data obtained from a subject who could not sleep in the laboratory recording situation. The activity rhythms had an additional harmonic around 90 min, which Sterman speculated to be the result of the influences of the mother's REM-NONREM cycle on the fetal activity cycle. In a

second experiment presented in the same paper, Sterman reported on ultradian rhythm of oral activity in cats. Subjects were trained to produce specific-localized EEG patterns in order to receive food. When the number of the particular EEG productions were plotted against time, they described a cycle similar to that of the REM-NONREM cycle of the cat. Furthermore, when transitions from sleep to wakefulness or wakefulness to sleep were examined, there appeared to be a phase continuity between waking performance and REM periods in sleep.

The sensitivity of the spiral after-effect (SAE) in detecting wakefulness periods subsequent to awakening from REM sleep and NONREM sleep led Lavie, Levy and Coolidge (1974), and Lavie, Lord and Frank (1974) to assume that the duration of the specific illusion might be a sensitive detector of the underlying ultradian rhythm. In the first study, 8 Ss were tested on the spiral after-effect for 8 hours, both during the day and during the night. Of the 14 available time series, ten revealed periodicities within the range commonly reported for the sleep rhythm. Similar results were obtained in the second experiment, in which high school students were continuously tested on the SAE from 4 PM to 12 midnight.

Recently, several researchers have reported on an approximate 100 min rhythmicity in physiological measurements as well as in behavioral measurements. Such rhythmicities were demonstrated in monkeys (Kripke et al., 1970), and in

human subjects performing continuous signal detection tasks (Orr, Hoffman and Hegge, 1973).

Three experiments were conducted in the present dissertation. The first was designed to determine the phase relationship between the REM-NONREM cycle and the waking cycle in the perception of the SAE. Assuming that the REM-NONREM cycle and the ultradian rhythms observed during wakefulness are fragments of the same biorhythm, which operates across both sleep and wakefulness, raises the question of the phase relationship between the two fragments of the rhythm. The "carry over" effects from a particular sleep stage, discussed earlier (Lavie, 1974; Lavie and Giora, 1973), and the continuation of the performance cycle with the REM-NONREM cycle in cats observed by Sterman (1972), suggest that the waking ultradian cycle is continuous with the REM-NONREM cycle upon awakening from sleep. To test the hypothesis that the two cycles are continuous across the transition from the sleep state to the waking state, the SAE phenomenon was utilized. The sensitivity of the SAE duration to the phase of the waking ultradian rhythm (Lavie, Lord and Frank, 1974; Lavie, Levy and Coolidge, 1974) makes this illusion an efficient tool for exploring the phase relationship between the waking and sleep fragments of the ultradian rhythms. Under the "continuation" hypothesis, it was expected that Ss awakened from NONREM sleep would reach earlier peaks in perception of the illusion than those awakened from REM sleep.

This follows from the assumption that, if the two cycles are continuous, Ss awakened from REM sleep would reach the subsequent "waking REM" period, which is associated with peak durations in the perception of the SAE, only after one complete cycle from the awakening, while Ss awakened from NONREM sleep would reach the first "waking REM" period after less than one complete cycle.

In addition, the influence of early vs. late awakening times was assessed. Several researchers reported that early retirement sleep periods demonstrate longer first REM period latencies than late retirement sleep periods (Taub and Berger, 1972; Webb and Agnew, unpublished results), and that the REM-NONREM cycle is shorter in the early morning hours than the early night hours (Taub and Berger, 1973). In light of these circadian effects on the REM-NONREM cycle, it was expected that if similar effects influence the waking ultradian rhythm then Ss awakened late at night, from the third REM period or following it, would demonstrate earlier peaks in perception under both REM and NONREM conditions than Ss awakened earlier at night, from the second REM period or following it.

The second experiment was designed to extend the differential effects of awakening from REM and NONREM sleep on the perception of the SAE to the perception of the beta movement (βM) (Phi phenomena). This apparent movement is obtained by successively exposing two stimuli at a short distance from one another. When the time interval between the stimuli is optimal,

the observer sees only one object moving across the field. As reported for the SAE, the βM was also found to be dependent on the physical characteristics of the stimuli (Lane and Horne, 1964; Saucer, 1954). It was also found to be depressed in Ss suffering from brain damage (Werner and Thuma, 1942; Bender and Teuber, 1949; Rouse, 1960). Hence, it was anticipated that the perception of the βM would also be influenced by the cortical states during wakefulness periods following REM and NONREM sleep.

The third experiment was designed to investigate the possible existence of ultradian rhythms, and their influence on the perception of the SAE and the βM. As noted earlier, it was shown that the duration of the SAE is modulated during the waking state in a rhythmic fashion, with a periodicity similar to that of the REM-NONREM cycle. Thus, it was anticipated that if the βM were also susceptible to the phase of the ultradian rhythm, its perceptual measurements should also demonstrate ultradian rhythmicity, with a periodicity similar to that of the SAE cycles, and with peaks and troughs concomitant to those of the SAE cycles. The dependent variables utilized in this experiment were those that were found to be the most sensitive to the cortical states following awakening from REM and NONREM sleep in the second experiment.

Each of these experiments will now be discussed in detail.

II EXPERIMENT 1

THE RELATIONSHIP BETWEEN THE REM-NONREM CYCLE AND THE ULTRADIAN RHYTHM IN THE PERCEPTION OF THE SPIRAL AFTER-EFFECT

METHOD

Subjects

Subjects were eight unpaid volunteers, four male high school students, aged 17 to 18 years, and four female students at the University of Florida, aged 19 to 21 years. All Ss were completely naive with respect to the experimental hypothesis, and agreed to avoid use of any kind of drugs during the course of the experimental period.

Dependent Variable

The Spiral After-Effect (SAE) is the illusion of continued motion that occurs after previous fixation of a rotating spiral. A spiral that appears to expand during the rotation period gives the after-effect of contraction, while an expanding after-effect occurs after fixating a spiral that appears to contract during rotation. The length, or duration, of the SAE, was utilized as the dependent variable in this experiment.

Apparatus

The spiral after-effect (SAE) apparatus has been described

in detail elsewhere (Lavie, Levy, and Coolidge, 1974). Briefly, it consisted of a 7 cm Archimedes type spiral mounted on the shaft of a rotor by a 1 cm black knob. It was rotated in a counterclockwise direction, at a speed of 100 rpm, for the duration of 10 sec each time. All tests were conducted in a small room (3x4 m), illuminated to a level of 25 lux. Subjects viewed the rotating spiral while sitting in a comfortable chair approximately 1 m from the center of the spiral, which was at the level of Ss' eyes. The duration of the illusion was measured in an adjacent room by a timer to the nearest five-hundredths of a second. The timer was started by the cessation of the real movement and stopped by the pressing of a microswitch.

Procedure and Design

Pairs of subjects slept in the laboratory for a total of four non-consecutive nights. On the first night, Ss came to the laboratory at about 10 PM. Upon their arrival they received a detailed explanation of the SAE phenomenon with several demonstrations. After the perception of the illusion was established, Ss practiced with the phenomenon for at least 55 min. During these practice sessions, Ss were instructed to fixate the central knob while the spiral was spinning, and to continue fixation after the spiral had stopped. They were also instructed to press a microswitch when they no longer saw the illusionary after-effect.

Subjects were carefully instructed to use the same criteria for judging the cessation of the illusion on every trial.

Following the practice session, Ss were fitted with electrodes to record their EEG and EOG, and were taken to the bedrooms. Three channels of EEG information were taken from each S on each of the experimental nights. Two channels of EEG were recorded, from approximately $O_z - P_z$ and $F_z - P_z$ and one channel of EOG was recorded, from the left side of the left eye to the right side of the right eye. Recording was done on a Grass model 6 D polygraph. All Ss retired before 12 midnight.

Table 1 illustrates the awakening design of this experiment. Each of the Ss was awakened on the four experimental nights from four different phases of the sleep cycle. Group 1, consisting of the four females, was awakened at: (1) 3 min after the beginning of REM no. 3 (Beginning REM condition - BR), (2) 10 min after the beginning of REM no. 3 (Middle REM condition - MR), (3) 3 min after the end of REM no. 3 (Beginning NONREM condition - BNR), and (4) 20 min after the end of REM no. 3 (Middle NONREM condition - MNR). Group 2, consisting of the four males, was awakened from the same phases of the sleep cycle, but with respect to REM no. 2.

The decision to awake one group from, or after REM no. 3, and one group from or after REM no. 2 was guided by the attempt to assess the circadian effects noted earlier (Taub and Berger, 1973) on the waking ultradian rhythmicity. It was ex-

TABLE 1

Awakening Design of Experiment 1

		NIGHT			
	S	1	2	3	4
GROUP 1	1	MNR	BNR	BR	MR
	2	MR	BR	BNR	MNR
	3	BNR	MR	MNR	BR
	4	BR	MNR	MR	BNR
GROUP 2	1	MNR	BNR	BR	MR
	2	MR	BR	BNR	MNR
	3	BNR	MR	MNR	BR
	4	BR	MNR	MR	BNR

pected that Ss of the first group would be awakened at least 2 to 3 hours later than Ss of the second group, and therefore the influence of the circadian effects could be assessed. The decision to awaken the Ss from both the beginnings and the middles of a particular sleep phase was made in order to assess possible cumulative effects of the particular sleep phase.

The time of awakening the Ss was made by a well practiced experimenter, who continuously monitored the polygraph. Immediately following the awakening, Ss were allowed to wash their faces and to adapt to the light, and then were tested on the SAE twice every 5 min for 180 min, in the same way as during the practice session prior to sleep. Approximately 2-3 min elapsed from the moment the lights were turned on until the first trial was given. The same Ss returned to the laboratory for three more nights separated by at least 24 hours, and were tested in a similar way on each of these nights. Prior to each experimental night, Ss were given a 55 min practice period with the SAE phenomenon. Between trials, Ss were allowed to read, study, listen to music, or be engaged in social interaction with each other and with the experimenters. Food, limited to light snacks and soft drinks, was supplied ad lib.

RESULTS

All the experimental Ss except for one accomplished successfully the four experimental nights. One S from Group 1,

who complained of a severe headache, finished only 120 min of the 180 test min following awakening from MNR.

As was expected, marked differences in awakening times were found between the two experimental groups. All Ss of Group 1 were awakened from, or following REM no. 3. The awakening times for this group ranged from 5:01 AM to 7:24 AM (median = 6:10 AM). The median awakenings for the REM and NONREM conditions were 6:03 AM and 6:11 AM, respectively. Subjects of Group 2 were awakened from, or following REM no. 2. Two Ss were awakened from REM no. 3, since the second REM period was too short to meet the awakening criterion. The awakening times for this group ranged from 2:00 AM to 5:15 AM (median = 3:12 AM). The median awakenings for the REM and NONREM conditions were 2:48 AM and 4:04 AM, respectively.

For each S and for each experimental period, a time series was constructed from the mean of the two trials taken every 5 min. The first trial of every experimental period was considered as a practice trial and excluded from the final analysis. Then, following transformation of the data to Z-scores (the raw data are presented in Appendix A), a pooled time series was constructed for each of the four experimental conditions for each of the groups, by averaging the corresponding time series (N=4) across Ss.[1] Due to the expected differences in response between the two groups, their

---

1. The MNR time series for Group 1 was pooled across 4 Ss for the first 120 min and pooled across three Ss for the rest of the experimental period.

data were analyzed separately.

The pooled time series for each of the awakening conditions, smoothed by a moving average process with N=4, are presented in Figures 1-4. Figure 1 presents the two time series for the BR and MR conditions for Group 1. The two REM time series have a similar course across the experimental period. Both begin from a high phase and cross the zero line 30 min (BR condition) and 55 min (MR condition), following the awakening. Then, following troughs at 80 min (BR condition) and 100 min (MR condition), they recross the zero line at 100 min (BR condition) and 120 min (MR condition), and reach subsequent peaks at 110 min (BR condition) and 135 min (MR condition), following the awakening. Figure 2, presenting the BNR and the MNR time series for the same group, reveals a different pattern of response. Both NONREM time series manifest a sharp decline during the first 30 min. The MNR time series begins below the zero line, while the BNR time series crosses the zero line 25 min following the awakening. Then, following troughs at 30 min (MNR condition) and 40 min (BNR condition), the BNR time series recrosses the zero line at 45 min and reaches a peak at 50 min, while the MNR time series reaches a peak at the same time without recrossing the zero line. Secondary peaks are observed at 120 min (BNR condition) and 135 min (MNR condition) following the awakening, or 70 min and 85 min following the first peaks.

Figure 3 presents the BR and MR time series for Group 2. As for the corresponding time series of Group 1, the two REM time series have similar courses across the three hours' experimental period. Both have initial high phases, then cross the zero line at approximately 35 min following the awakening, and, following troughs at 75 min (MR condition) and 95 min (BR condition), recross the zero line at 135 min, and reach subsequent peaks 140 to 145 min following the awakening from sleep. The two NONREM time series are presented in Figure 4. While the MNR time series begins from high phase, the leading phase of the BNR time series is more depressed. Both time series cross the zero line at approximately 30 to 35 min, and reach troughs at 50-60 min following the awakening. Then, the time series recross the zero line at 70 min (MNR condition) and 85 min (BNR condition), and reach subsequent peaks at 75 min (MNR condition) and 95 min (BNR condition), following the awakening. Both time series have marked downward trends during the last hour of the experimental periods.

In summary, Table 2 presents the peaks and troughs, detected by visual observation, for the eight time series. As can be seen from the table, the two NONREM time series for both groups reveal earlier peaks than the REM time series; moreover, the NONREM time series for Group 1 has two peaks within the experimental period. As for between-group differences, both REM time series of Group 1 (median awakening, 6:10) reach peaks earlier than the REM time series of Group 2

Figure 1: BR (filled circles) and MR (empty circles) SAE time series of Group 1.

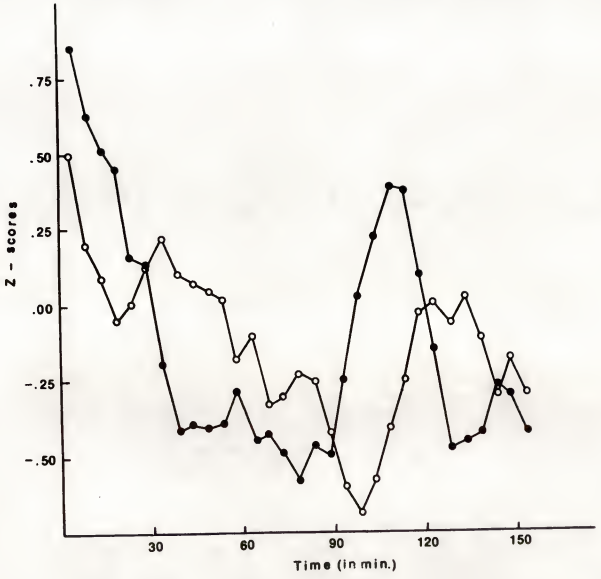

.75
.50
.25
.00
-.25
-.50
Z - scores
30
60
90
120
150
Time (in min.)

Figure 2: MNR (filled circles) and BNR (empty circles) SAE time series of Group 1.

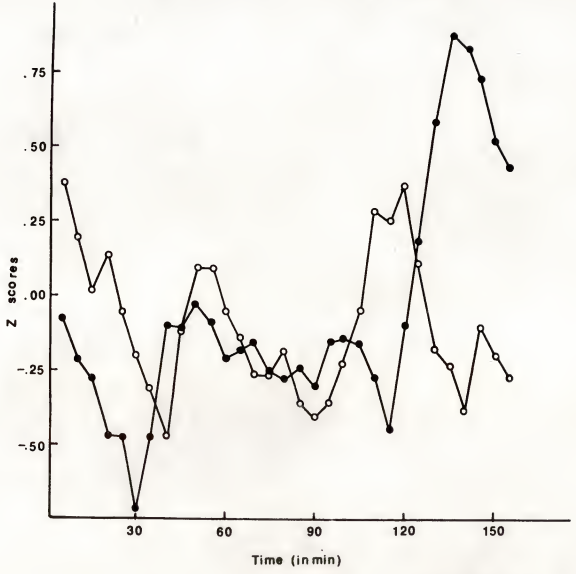

.75
.50
.25
.00
-.25
-.50
Z scores
30
60
90
120
150
Time (in min)

Figure 3: BR (filled circles) and MR (empty circles) SAE time series of Group 2.

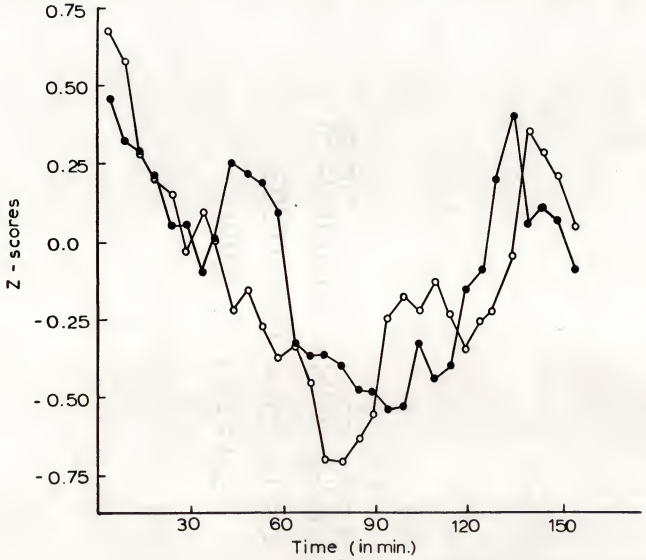

0.75
0.50
0.25
0.0
- 0.25
- 0.50
- 0.75
Z - scores
30
60
90
120
150
Time (in min.)

Figure 4: MNR (filled circles) and BNR (empty circles) SAE time series of Group 2.

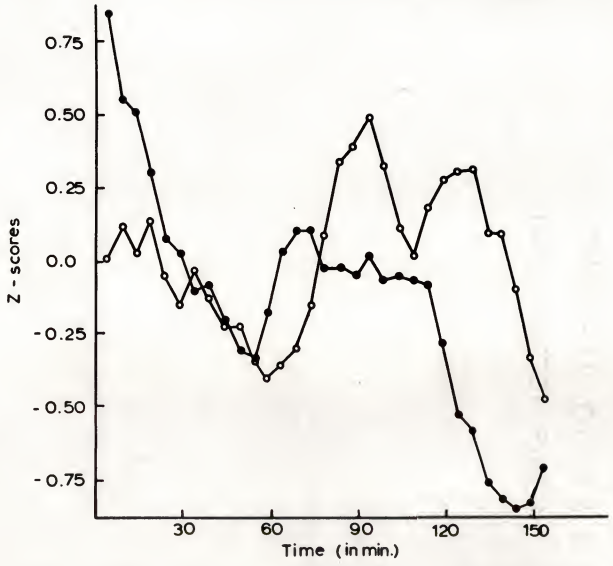

0.75
0.50
0.25
0.0
- 0.25
- 0.50
- 0.75
Z - scores
30
60
90
120
150
Time (in min.)

TABLE 2

Peaks and Troughs for the Eight Time Series Detected by Visual Observation (In min from Awakening)

		1st trough	1st peak	2nd trough	2nd peak
GROUP 1	BR	80	110	-	-
	MR	100	135	-	-
	BNR	40	50	90	120
	MNR	30	50	115	135
GROUP 2	BR	95	140	-	-
	MR	75	145	-	-
	BNR	50	95	-	-
	MNR	50	75	-	-

(median awakening, 3:12): 110 min, 125 min, and 140 min and 145 min, respectively. Similarly, the NONREM time series of the first group reach earlier peaks than the NONREM time series of the second group: 50 min, and 70 min, 95 min, respectively. No marked differences between the BR and the MR, and the BNR and the MNR time series are observed for the two groups.

Due to the similarity between the BR and MR, and the BNR and MNR time series within each group, they were pooled for each of the groups. The pooled time series are presented in Figures 5 and 6. The REM time series for Group 1 (Figure 5) begins from a high phase, crosses the zero line at 35 min, and recrosses it at 115 min, when it reached a peak at 120 min following the awakening. The NONREM time series, beginning from a lower phase, immediately crosses the zero line and reaches a trough at 30 min, and then recrosses the zero line to reach the first peak at 50 min following the awakening. A secondary peak is observed at 80 min following the first peak. Figure 6 presents the REM and NONREM time series for Group 2. The REM time series for this group resembles that of Group 1, and differs only in the location of the peak: 140 vs. 115 min following the awakening. The NONREM time series has an initial high phase like the REM time series, except for the fact that it crosses the zero line 20 min earlier than the REM time series. However, it reaches a trough 20 min earlier than the REM time series, then recrosses

Figure 5: Pooled REM (empty circles) and NONREM (filled circles) SAE time series of Group 1.

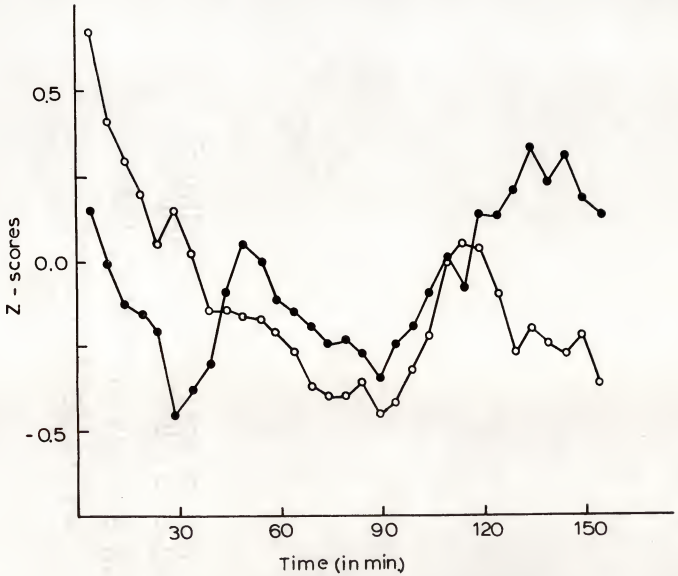
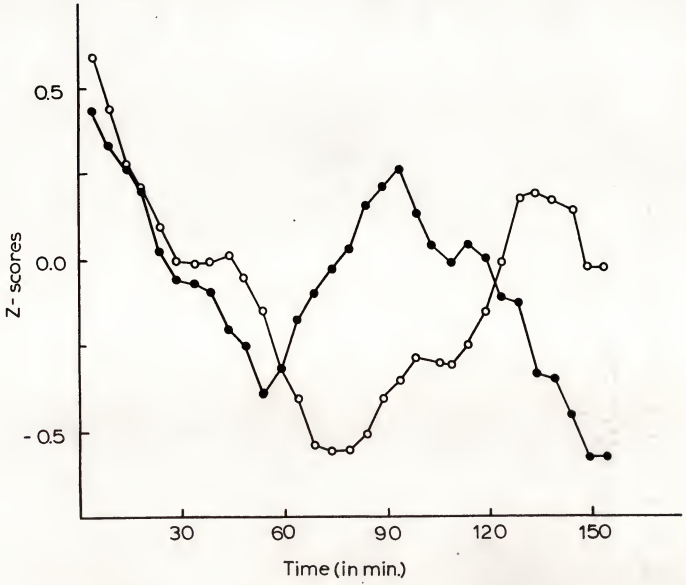

0.5
0.0
-0.5
Z - scores
30
60
90
120
150
Time (in min)

Figure 6: Pooled REM (empty circles) and NONREM (filled circles) SAE time series of Group 2.


0.5
0.0
- 0.5
Z - scores
30
60
90
120
150
Time (in min.)

the zero line at 75 min, and reaches a subsequent peak at 95 min, following the awakening.

To confirm the differential trends in response detected by the visual observation and predicted by the experimental hypothesis, the polynomial regression analysis was utilized.[2] With this method, polynomials of different orders are fitted to the data, and the degree of fitness is evaluated by the F-test. In accordance with the predicted earlier peaks for the NONREM time series, it was expected that they would best be fitted by polynomials of the third order, or by polynomials of higher orders, while the REM time series would be best fitted by second order polynomials.

Each of the BR, MR, BNR, and MNR pooled time series was subjected to fifth order polynomial regression analysis. The summary tables of these analyses for each of the time series are presented in Appendix A. Table 3 presents the F ratios and the significance levels of the (five) components, for each of the experimental conditions. All the time series had at least one significant component. For the first group, the BNR time series revealed a significant cubic component, and the MNR time series revealed a highly significant quintic component, in addition to a significant linear component. On the other hand, the BR and MR time series revealed a marked

---

2. All statistical analyses were performed on the raw data.

TABLE 3

The F Ratios and the Significance Levels of the Fifth Order Polynomial Regression Conducted on the BR, MR, BNR, and the MNR Time Series for the Two Groups.

		Linear	Quadratic	Cubic	Quartic	Quintic
	BNR	F=2.78	F < 1	F=4.81	F < 1	F <1
		n.s.	n.s.	p <.05	n.s.	n.s.
	MNR	F=8.90	F=4.03	F=2.32	F < 1	F=9.27
GROUP 1		p <.005	n.s.	n.s.	n.s.	p <.005
	BR	F=12.43	F=10.89	F=10.46	F < 1	F=6.22
		p <.005	p <.005	p <.005	n.s.	p <.025
	MR	F=7.3	F=5.94	F < 1	F < 1	F=2.64
		p <.025	p <.025	n.s.	n.s.	n.s.
	BNR	F < 1	F=5.72	F=9.74	F=1.15	F=8.76
		n.s.	p <.05	p <.005	n.s.	p <.01
	MNR	F=56.23	F=1.98	F=6.79	F=14.87	F=1.82
GROUP 2		p <.001	n.s.	p <.025	p <.001	n.s.
	BR	F=3.71	F=5.98	F < 1	F=4.15	F=3.97
		n.s.	p <.025	n.s.	n.s.	n.s.
	MR	F=7.08	F=24.29	F=6.71	F=2.52	F=1.41
		p <.025	p <.005	p <.025	n.s.	n.s.

quadratic component. The BR time series also revealed significant linear and cubic components and a significant quintic component. The MR time series revealed an additional linear component.

For Group 2, the two NONREM conditions revealed significant cubic components, for the BNR time series, and for the MNR time series. In addition, the BNR time series had a significant quintic component and quadratic component. The MNR time series had additional significant linear and quartic components. As for the first group, both the BR and the MR time series had significant quadratic components, for the BR and for the MR time series. The latter also revealed significant linear and cubic components.

Similar polynomial regression analysis was performed on the pooled REM and NONREM time series for the two groups. The results presented in Table 4 support the individual analyses. While both REM time series had the highest F ratios for the quadratic components, the NONREM time series had the highest F ratios for higher components. In addition, highly significant linear trends were observed for the REM and NONREM time series of Group 2, and the REM time series of Group 1.

While the polynomial regression analysis enables assessment of the general trends of the time series, it does not supply any information with respect to the phase differences between the time series. To determine such phase differences, the cross-correlation method was utilized; it would reveal

TABLE 4

The F Ratios and the Significance Levels of the Fifth Order Polynomial Regression Conducted on the Pooled REM and NONREM Time Series for the Two Groups.

		Linear	Quadratic	Cubic	Quartic	Quintic
GROUP 1	REM	F=25	F=21.167	F=9.83	F < 1	F < 1
		p<.001	p<.001	p<.005	n.s.	n.s.
	NON-REM	F=.96	F=5.48	F=9.41	F < 1	F=6.78
		n.s.	p<.05	p<.005	n.s.	p<.025
GROUP 2	REM	F=32.41	F=80	F=15.2	F=20.43	F=16.78
		p<.001	p<.001	p<.001	p<.001	p<.001
	NON-REM	F=28.76	F < 1	F=16.56	F=3.62	F=9.49
		p<.001	n.s.	p<.001	n.s.	p<.005

cyclic activity common to two variables as well as the "lead-lag" relations between them. The latter relationship is determined by observing the lags for which the maximum cross-correlation coefficients were obtained. Thus, it was expected that if the awakening conditions differentially influence the response to the SAE, the cross-correlation function between the two REM time series and between the NONREM time series would show smaller phase differences than the cross-correlation function between the REM and NONREM time series for each of the groups.

First, every time series was cross-correlated with every other time series up to a lag of 85 min, within each group of Ss. Then, three cross-correlation functions were established for each group of Ss: Two functions were established from crossing the BR and MR time series, and the BNR and MNR time series, and a pooled cross-correlation function was established from averaging across all the possible pairs of REM and NONREM time series. To permit the construction of a pooled cross-correlation function, the cross-correlation coefficients were transformed to Z-scores before the averaging procedure. Figures 7, 8, and 9 present the three cross-correlation functions for the Ss of Group 1. The fact that Ss of this group manifested 2 peaks under the NONREM conditions is confirmed by the cross-correlation functions. Maximum coefficients between the two NONREM time series are obtained by lagging the series 10 and 55 min, or by leading the series 20 and 75 min. The

maximum cross-correlation coefficients for the two REM time series are obtained by lagging the series 25 min, or by leading the series 30 min. The approximate 25 to 20 min phase difference between the two REM time series agrees with the results of the polynomial regression, which indicates significant cubic and quintic components only for the BR time series, in addition to the highly significant quadratic component. Due to the fact that the REM time series for this group peaks at approximately the same time as the second peaks of the NONREM time series, the pooled cross-correlation function between the REM and NONREM time series reveals a relatively high coefficient for a lag of 0. However, additional peaks can be observed for the lags of 40 and 60 min, which suggests phase differences between the first peaks of the NONREM time series and the peaks of the REM time series.

Figures 10, 11, and 12 display the three cross-correlation functions for Group 2. As can be seen from Figure 10, the two REM time series are essentially in phase across the experimental periods. The maximum cross-correlation coefficients are obtained by lagging or leading one with respect to the other by 5 min. The two NONREM time series are also found to be in phase, and the maximum coefficients (Figure 11) are obtained by lagging the time series by 15 min, or leading it by 80 min. The maximum cross-correlation coefficient at a lag of 40, observed for the pooled REM-NONREM cross-correlation function (Figure 12) suggests a phase difference of approximately 40

Figure 7: Cross-correlation function between the BNR and the MNR time series for Group 1.

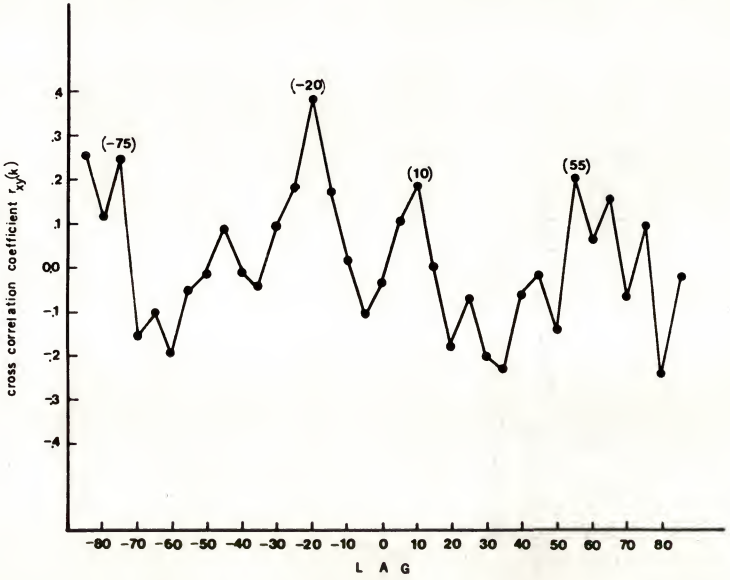

cross correlation coefficient $r_{xy}(k)$
.4
.3
.2
.1
0.0
-.1
-.2
-.3
-.4
(-75)
(-20)
(10)
(55)
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
L A G

Figure 8: Cross-correlation function between the BR and the MR time series for Group 1.

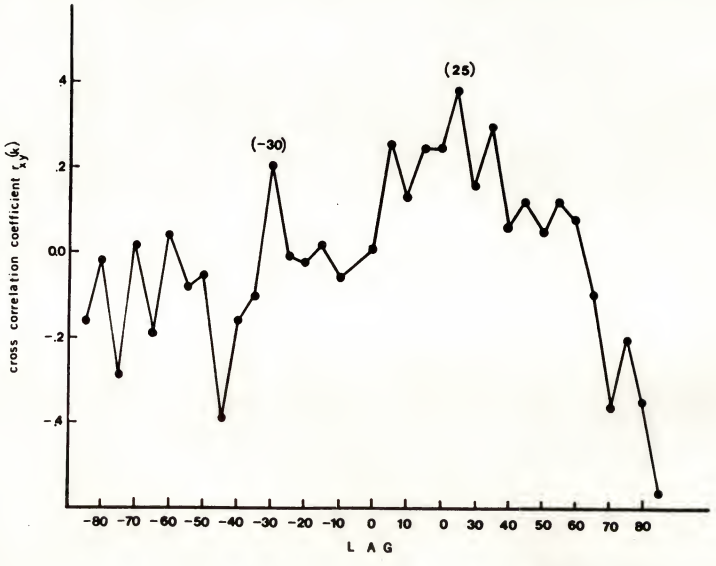

(25)
(-30)
.4
.2
0.0
-.2
-.4
cross correlation coefficient $r_{xy}(\hat{\omega})$
-80 -70 -60 -50 -40 -30 -20 -10 0 10 0 30 40 50 60 70 80
L A G

Figure 9: Pooled cross-correlation function between the REM and the NONREM time series for Group 1.

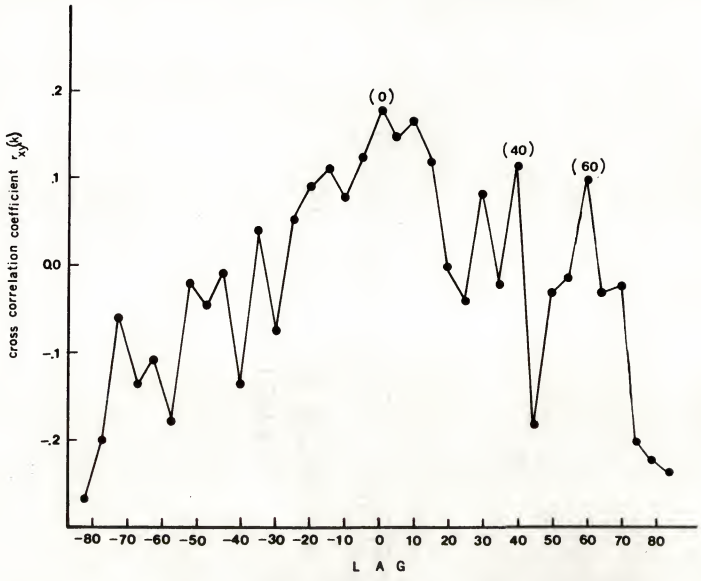

cross correlation coefficient $r_{xy}(k)$
.2
.1
0.0
-.1
-.2
(0)
(40)
(60)
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
L A G

Figure 10: Cross-correlation function between the BR and the MR time series for Group 2.

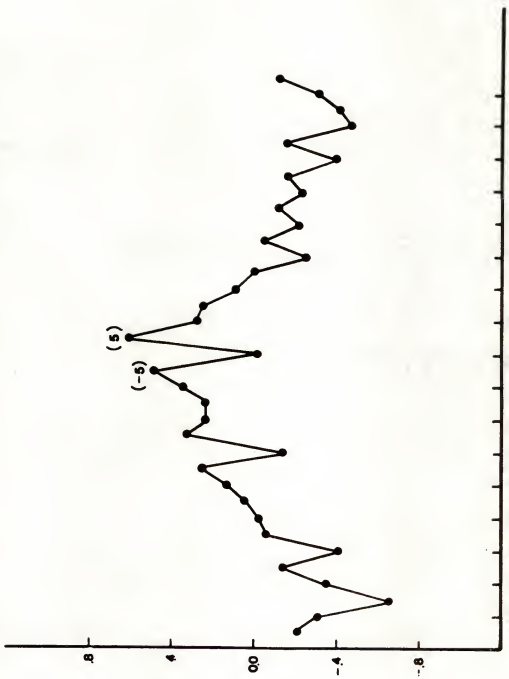

cross correlation coefficient $r_{xy}(k)$
.8
.4
00
-.4
-.8
(5)
(-5)
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
L A G

Figure 11: Cross-correlation function between the BNR and the MNR time series for Group 2.

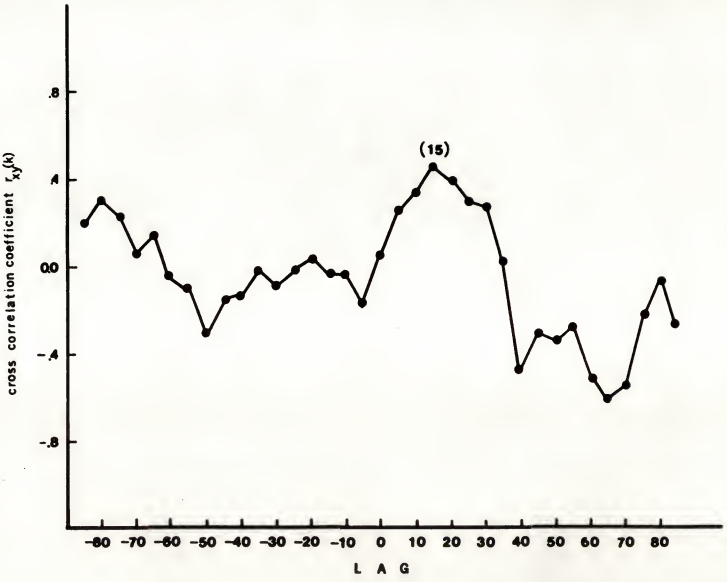
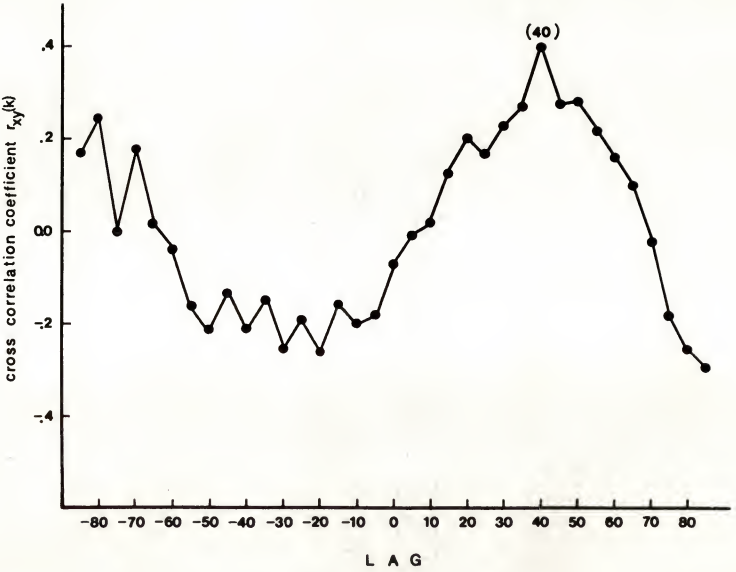

.8
.4
0.0
-.4
-.8
(15)
cross correlation coefficient $r_{xy}(k)$
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
L A G

Figure 12: Pooled cross-correlation function between the REM and the NONREM time series for Group 2.


(40)
.4
.2
0.0
-.2
-.4
cross correlation coefficient $r_{xy}(k)$
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
L A G

min between the time series of the two conditions, and these results agree both with the visual observation of the time series and with the results of the polynomial regression analysis.

At last, the influence of the awakening condition on the immediate response to the spiral after-effect was evaluated. The mean of the second and third trials was calculated (following the Z transformation) for each of the subjects, for each of the experimental periods; then, a simple Latin square ANOVA was performed on the means separately for the two groups. No significant effects due to the awakening condition are found for the two groups. Observing the means of the four experimental periods for each S reveals strong order effect. Four of the Ss had the order: mean experimental period 1 > period 2 > period 3 > period 4. For three other Ss, the mean of the first period was higher than the following periods. Only one S demonstrated the opposite trend across the four nights.

In summary, the main results of this experiment showed: (1) Within the groups, there was a difference between the REM and the NONREM time series. In both groups of Ss, the NONREM time series peaked earlier than the REM time series. (2) In both groups there was a similarity between the course of the two REM time series, and the course of the two NONREM time series. However, in both cases the REM time series had smaller phase differences than the NONREM time series.

(3) Between groups, there were differences in the course of the time series. Group 1 reached the first peak, in both the REM and the NONREM time series, earlier than Group 2. (4) There was no difference in response during the first two trials due to the awakening condition.

DISCUSSION

The results of this study indicate that Ss, who were awakened from different phases of the sleep cycle, manifested different trends in the perception of the SAE, when tested for three continuous hours following the awakening. If it is accepted that the periodic alternations in the perception of the illusion demonstrated by Lavie, Levy and Coolidge (1974) and Lavie, Lord and Frank (1974), reflect an underlying, ultradian biorhythm during the waking hours which parallels the REM-NONREM cycle, then the hypothesis that the differential trends in the response to the SAE represent differential phasing of the waking counterpart of the REM-NONREM cycle due to the awakening condition seems valid. This supports the hypothesis stated in the introduction, that the waking and sleep fragments of the ultradian biorhythms are continuous, which agrees with the earlier results reported by Sterman, using cats as subjects (1972). No difference in response was found between the beginning and middle awakening conditions; and thus, the possibility of a cumulative effect of the particular sleep stage on the response can be eliminated.

As was expected under the "continuation" hypothesis, subjects in both groups awakened from REM sleep reached the first peak in perception later than when awakened from NONREM sleep. Both awakenings from NONREM sleep resulted in earlier peaks than awakenings from the REM conditions. The between-group differences were also in agreement with the experimental hypothesis, and with the current knowledge regarding the properties of the REM-NONREM cycle (Taub and Berger, 1973). Under both the REM and NONREM conditions, Ss of Group 1, whose median awakening time was 6:10 AM, had shorter peak latencies than Ss of Group 2, whose median awakening time was three hours earlier.

As reported by Taub and Berger (1973), the first REM period latencies of sleep periods beginning at midnight were significantly longer than the latencies for sleep periods beginning at 4 AM; the means were 81.2 min (SD = 33 min) and 48.4 min (SD = 16.6 min), respectively. Similar differences between late and early sleep periods with respect to the first REM period latencies and the amount of REM sleep were reported by Agnew and Webb (1973). In addition to the differential distribution of the REM latencies across the night, Taub and Berger also reported that the length of the REM-NONREM cycle is significantly shorter for sleep periods beginning at 4 AM (mean = 81.5 min) than for sleep periods beginning at midnight (mean = 98.5 min). The fact that Ss awakened at 6 AM reached earlier peaks in perception than those awakened 3 hours earlier, suggests that the cyclicity in the perception of the illusion is

also modified by a circadian modulator, as is the REM-NONREM cycle, and thus supports the conclusion that both rhythms reflect the same biorhythm operating across sleep and wakefulness.

Due to the sex difference between the two groups of Ss, an alternative explanation can be offered; that the observed differences in response between the two groups were due to sex differences in response to the SAE, or due to sex differences in the phasing of the ultradian rhythm. However, such an explanation seems remote, since no sex differences were observed with respect to the perception of the SAE (Stern, 1959; Page et al., 1957) and with respect to the periodicity in the perception of the illusion (Lavie, Lord and Frank, 1974).

The suggestion that the waking and sleep portions of the 90 min ultradian rhythm are continuous can help to explain the often reported high variance of the latency of the first REM period. Agnew and Webb (1973) reported on first REM latencies ranging from 50 to 409 min; moreover, according to these authors only 24% of the REM onsets occurred within 10 min of 99 min from sleep onset. Taub and Berger (1973) also presented data suggesting high variance of the latency of the first REM period. For instance, the standard deviation of the mean latencies of the first REM period was 69.4 for sleep periods beginning at 8 PM, 41.2 min for sleep periods beginning at 10 PM, and 33 min for sleep periods beginning at midnight. The high variability of the latencies can be explained by assuming that the REM-NONREM cycle is continuous with the

waking fragments of the cycle, since the waking cycle was found to be continuous with the sleep cycle. Hence, Ss would manifest earlier REM periods when sleep onset occured at a trough, or "waking NONREM" periods, in their waking rhythm, and they would likewise manifest late REM periods when sleep onset occured at a peak, or "waking REM" periods in their waking cycle. However, the fact, that at least 40 min of NONREM sleep must elapse before normal Ss retiring around midnight can reach the first REM period, suggests that the transition from waking to sleep may temporarily interrupt the course of the ultradian rhythm.

The lack of effect of the awakening condition on the initial phase of the SAE cyclicity is apparently contradictory to the results reported earlier by Lavie and Giora (1973) and Lavie (1974), who demonstrated longer durations of the SAE following awakening from REM sleep than following awakenings from NONREM sleep. However, while in the earlier studies the comparisons between the REM and the NONREM durations was made within one experimental night, in the present study all such comparisons were made across two different nights. In addition, the experimental sessions in the earlier study lasted no longer than 15 min, while in the present study, Ss were tested for three continuous hours during each experimental session. The reduction in novelty of the experimental situation and the experimental task, and the increased boredom across the experimental nights, usually indicated a "levelling

off" of the illusion across the four experimental periods, reflected in the successive reduction of the mean duration for each experimental period. Analysis of the 11 trials conducted prior to sleep on each of the experimental nights also revealed a strong order effect. For instance, S 4 Group 2, (Table A-14) manifested mean durations of 11.93, 8.07, 6.97, and 5.67 sec during the first, second, third and fourth practice sessions. It is possible that the strong "levelling off" of the illusion masked the differences in the leading phases due to the awakening conditions. Similar successive reduction in the duration of the illusion was reported by Kragh (1955).

Further research is needed in order to elaborate the nature of this reduction, and to assess the variables controlling it.

III EXPERIMENT 2
DIFFERENTIAL RANGES OF THE BETA MOVEMENT FOLLOWING AWAKENING FROM REM AND NONREM SLEEP

METHOD

Subjects

Subjects were 10 unpaid volunteers, four males and six females, aged 18 to 21 years, who were enrolled in an introductory psychology course at the University of Florida. All the Ss were completely naive with respect to the experimental hypothesis. They were requested to avoid consuming any kind of drugs during the 24 hours preceding each of the experimental nights.

Dependent Variable

The Beta Movement (βM) illusion is obtained by succesively exposing two stimuli at a short distance apart; when the time interval between the two stimuli is optimal, the observer sees only one object moving across the field. The illusion can also be produced by alternately flashing on and off two proximal lights. When the frequency of the alternation is optimal, the observer sees only one light moving across the field. The latter technique was employed in the present experiment. Four perceptual measurements, to be discussed later, were used as dependent variables in this experiment.

Apparatus

Beta Movement. Operating from multivibrator circuit (Saucer, 1956), neon Westinghouse lamps were illuminated, with light presented alternately through each of two identical apertures, 5 cm in diameter, which were at a distance of 13 cm from each other, measured center to center. The light source produced a constant 15 ml level of illumination. A head rest was used to insure that Ss viewed the apertures at a constant distance of 69 cm, and with fixed position of the head.

The bench containing the optical system was set up in a room that could be darkened completely. During the experimental trials, the small lamp which illuminated the control board of the vibrator switch was not visible to the subject. Flash rate was varied from 1 flash per second (fps) to 7 fps.

Procedure and Design

Subjects slept for two non-consecutive nights in the sleep laboratory. On the first night, Ss came to the laboratory at approximately 10 PM. Upon their arrival, they were taken to the test room, and received a detailed explanation of the beta movement. Then, following 2 min of dark adaptation, Ss were given some practice trials to familiarize them with the phenomena. After the perception of the beta movement was established, the upper and lower thresholds of the apparent movement were determined. To determine the thresholds, the

method of limits was utilized. Each S received 3 blocks of 6 ascending and 6 descending trials, in alternation. Subjects were instructed to report, by saying "motion" when they saw the light in full motion from one position to the other, and to report "no motion" when they no longer saw one light moving from one position to the other. A two min rest period was given between blocks of trials. The descending - ascending order of trials was alternated for each block of trials, and for each successive subject tested.

After the first experimental session, which lasted approximately 20 min, subjects were fitted with electrodes to record their EEGs and EOGs, and were taken to the bedrooms and were connected to the polygraph. At least three channels of information were taken from each subject; two channels of EEG, from approximately O_z - P_z and F_z - P_z and one channel of EOG, from the left side of the left eye to the right side of the right eye. Recordings were done on a Grass model 6D polygraph.

To determine when to awaken the S during the night, a well practiced experimenter continuously monitored the polygraph, and when the electrophysiological records met the criteria of a particular awakening, a second experimenter entered the subject's room and turned the lights on. Immediately upon awakening, Ss were taken to the test room, and following 2 min of dark adaptation were tested in a way similar to the trials made prior to sleep, to determine their upper

and lower (βM) thresholds. The experimenter conducting the post-awakening trials was naive with respect to the awakening condition. The average elapsed time from the moment the lights were turned on until the first test was given was approximately 2.5 min. The approximate time for the post-awakening experimental sessions was 20 min.

Table 5 illustrates the experimental design with respect to the test conditions. Each S was awakened twice during each experimental night. Five Ss, randomly chosen, two males and three females, were awakened during one night, either 20 min after the end of the first REM period and 7 min after the beginning of the second REM period (A1), or 7 min after the beginning of the second REM period and 20 min after the end of the third REM period (A2). The other 5 Ss, two males and three females, were awakened during one night, either 10 min after the end of the first REM period and 3 min after the beginning of the second REM period (B1), or 3 min after the beginning of the second REM period and 10 min after the end of the third REM period (B2). The order of awakening was counterbalanced across Ss and across nights.

As in the first experiment, the decision to awaken Ss from both the beginning and the middle of particular sleep stages was made as an attempt to assess possible cumulative effects of the particular sleep stage. Subjects returned to the laboratory at least two days after the first experimental night, and were re-tested, prior to sleep and following two awakenings from sleep, in a way similar to the first night.

TABLE 5

Awakening Order - Experiment 2

	S	DAY 1	DAY 2
	1	A1	A2
	2	A2	A1
GROUP 1	3	A1	A2
	4	A2	A1
	5	A1	A2
	6	B2	B1
	7	B1	B2
GROUP 2	8	B2	B1
	9	B1	B2
	10	B2	B1

A1 - 20 min after the end of REM 1
7 min after the beginning of REM 2

A2 - 7 min after the beginning of REM 2
20 min after the end of REM 3

B1 - 10 min after the end of REM 1
3 min after the beginning of REM 2

B2 - 3 min after the beginning of REM 2
10 min after the end of REM 3

RESULTS

Four perceptual measurements were constructed for each block of trials for each of the experimental sessions: (1) the mean lower limit of the βM, (2) the mean upper limit of the βM, (3) the median of the 12 ascending and descending trials, and (4) the range of perception, i.e., the difference between the mean upper and lower limits.

Repeated measurements in a hierarchial design ANOVA (Myers, 1969) (Ss X days X test conditions X blocks by experimental group), were performed on each of the utilized dependent variables. Summary tables of the ANOVAs performed and the raw data for each variable are presented in Appendix B. The ANOVA performed on the mean lower limit revealed no significant effects due to any of the main or interaction effects. The ANOVA performed on the mean upper limit revealed barely significant F ratio for the interaction effect of blocks X days ($F = 3.77$, $df = 2,16$, $p < .05$). The mean upper limits of the three blocks of trials, pooled across all experimental conditions, for the two experimental nights are presented in Figure 13. The different pattern of response for the two experimental nights explains the barely significant interaction effect. The ANOVA performed on the medians yielded significant F ratios for the block effects ($F = 4.02$, $df = 2,16$, $p < .05$), and for the interaction effect of blocks X days ($F = 4.03$, $df = 2,16$, $p < .05$). Subsequent analysis (Newman-Keuls) revealed significant differences between block no. 1

and block no. 2 ($p < .05$), and block no. 1 and block no. 3 ($p < .05$). The medians of the three blocks of trials pooled across all experimental conditions for the two experimental nights are presented in Figure 14. The different pattern of response for the two experimental nights explains the significant interaction effect.

The ANOVA performed on the ranges of the apparent movement yielded significant F ratios for the test conditions effect ($F = 11.06$, $df = 2,16$, $p < .005$) and for the blocks effect ($F = 7.83$, $df = 2,16$, $p < .01$). Figure 15 presents the mean ranges for the three test conditions for the two days of testing, averaged across both groups. Subsequent analysis (Newman-Keuls) revealed that the ranges of the tests conducted following the REM awakenings were significantly wider than the ranges of the tests conducted following both NONREM awakenings ($p < .01$) and the ranges of the tests conducted prior to sleep ($p < .01$). The latter were also found to be significantly wider than the ranges of the NONREM tests ($p < .05$). Similar analysis revealed significant differences between block no. 1 and block no. 3 ($p < .01$), and block no. 1 and block no. 2 ($p < .05$).

The fact that the test condition had a significant effect only on the ranges of the βM needs some further elaboration. Figure 16 presents the upper and lower limits of the three experimental conditions, pooled across the experimental groups, days and blocks of trials. The figure indicates that there

Figure 13: Beta movement upper limits of perception pooled across Ss and experimental conditions for the two experimental days and three blocks of trials.

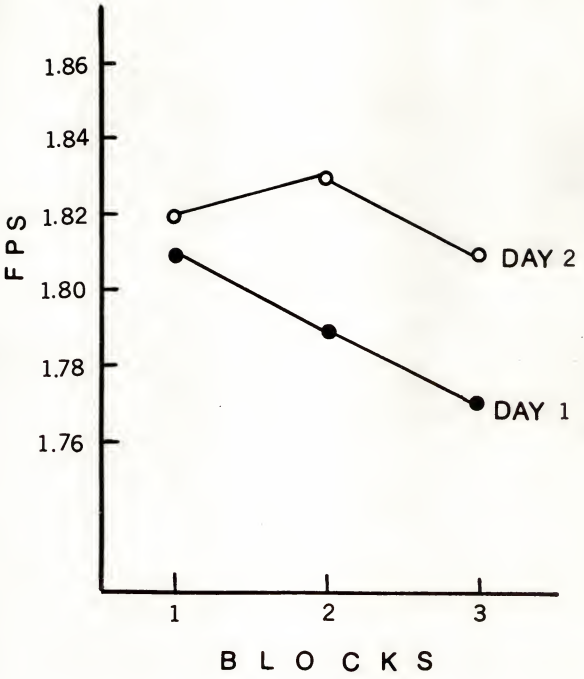

1.86
1.84
1.82
1.80
1.78
1.76
FPS
DAY 2
DAY 1
1
2
3
BLOCKS

Figure 14: Beta movement medians of perception pooled across Ss and experimental conditions for the two experimental days and the three blocks of trials.

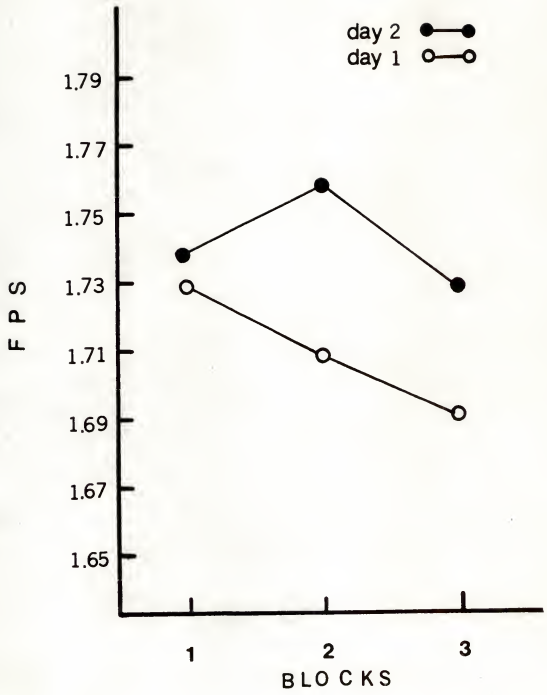

day 2
day 1
1.79
1.77
1.75
1.73
1.71
1.69
1.67
1.65
F P S
1
2
3
BLO C KS

Figure 15: Beta movement ranges of perception for NONREM awakening (NR), REM awakening (R), and for tests conducted prior to sleep (W).

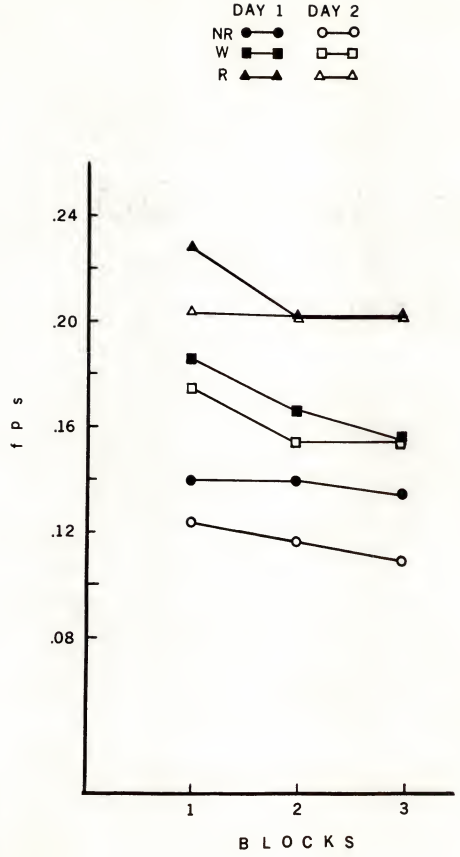
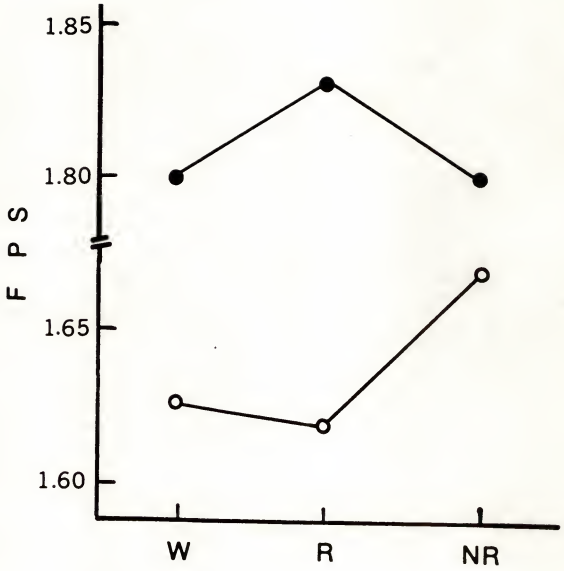

DAY 1
DAY 2
NR
W
R
.24
.20
.16
.12
.08
f p s
1
2
3
B L O C K S

Figure 16: Beta movement upper and lower limits of perception pooled across the experimental groups, days and blocks of trials for the NONREM awakenings (NR), REM awakenings (R), and for tests conducted prior to sleep (W).


1.85
1.80
1.65
1.60
F P S
W
R
NR

was a relative elevation of the upper limit and suppression of the lower limit under the REM condition, and a relative suppression of the upper limit and elevation of the lower limit under the NONREM condition, as compared to the waking limits. However, inspection of the raw data for the upper and lower limits, presented in Appendix B, reveals that many Ss did not conform to this pattern of response, but demonstrated either elevation of the upper limit, or suppression of the lower limit under the REM condition, or, suppression of the upper limit, or elevation of the lower limit under the NONREM condition. Therefore, only ranges of perception were found to be influenced by the test condition, with no significant effects on the upper and lower limits of the apparent movement.

DISCUSSION

The results of the present study indicate some differences in perceptual processes following awakening from REM sleep and NONREM sleep. On the average, the range of perception of the βM was almost twice as large following REM awakenings as following NONREM awakenings. The differential effects of the awakenings from the two phases of sleep support earlier results, which reported similar differences (Lavie and Giora, 1973; Lavie, 1974). As observed in the first experiment, no difference in response was found between the beginning and

middle awakening conditions.

All those studies, and the results of the present study, suggest higher levels of cortical activity following awakening from REM sleep than following awakening from NONREM sleep. The well documented data on the differences in cortical activity levels between the two phases of sleep, as manifested in EEG (Dement and Kleitman, 1957), brain temperature (Reite and Pegram, 1968) blood pressure (Coccagna et al., 1971), metabolism (Brebbia and Altshuler, 1968), gastric acid secretion (Kales and Tan, 1969) and genital engorgement (Karacan et al., 1972), pointed out that these activities, or at least part of them, should penetrate into the waking state, following interruption of REM sleep, and part of them are responsible for the differential response, found on the behavioral level (Lavie and Giora, 1973; Lavie, 1974). The idea expressed in the previous experiment, that the waking and the sleep portions of the ultradian biorhythm are continuous across the transition from sleep to waking was further substantiated in the present experiment.

Due to the similarity between the REM state and the waking state, one would expect that the responses following the REM awakenings would be similar to the waking responses e.g., the responses to the βM obtained prior to sleep. However, the waking ranges of the βM were found to be intermediate between the REM and NONREM responses. This can be explained by assuming that the ranges of the apparent movement would

also be sensitive to the phases of the waking ultradian rhythm, as was demonstrated in the perception of the SAE (Lavie, Lord and Frank, 1974). Thus, the mean range for the waking βM, taken irrespective of the phase of the ultradian rhythm, would be expected to result in some intermediated response, as was observed in the present experimental results. The possible susceptibility of the βM to the ultradian rhythm will be demonstrated in the third experiment.

Comparison of the results of the first and second experiments suggests that the range of the βM is a more sensitive indicator for wakefulness periods following awakenings from REM and NONREM sleep, than is the duration of the SAE. While in the first experiment no differences were found in the immediate response to the SAE due to the awakening condition, the response to the βM following the awakening from the two phases of sleep was significantly different, both within and between nights. This may be attributed to at least two factors: first, it may be that the cortical mechanisms, or processes, responsible for the SAE are less sensitive to the cortical states associated with the post-REM and post-NONREM wakefulness periods than the cortical mechanisms responsible for the βM, and second, it may be that the perception of the βM is more easily established, and is less dependent on certain subjective criteria than the SAE duration, and is therefore less variable than the latter.

The physiological mechanisms responsible for the βM are still an enigma. Several researchers attributed the apparent movement to cortical mechanisms (Werner and Thuma, 1942; Rouse, 1960; Wilson, 1955). Although the results of the present study cannot resolve the question of the origin of the apparent movement, the differential effects on perception of the awakening from the two phases of sleep give some support to the theory that cortical mechanisms may be responsible for the phenomenon.

There is no immediate explanation for the fact that only the range of perception was susceptible to the awakening conditions. The general trend, indicated by Figure 16, for suppression of the upper limit and elevation of the lower limit under the NONREM condition, and elevation of the upper limit and suppression of the lower limit under the REM condition, might suggest that the cortical states associated with the post-REM and post-NONREM wakefulness periods, differentially influence the upper and lower thresholds of the illusion. However, the facts that (1) no significant effects on the upper and lower limits were found due to the test conditions, and (2) the inconsistency in the response observed in the raw data, might suggest that the susceptibility of the range of the βM to the post-awakening cortical state represents a "locking in" phenomenon for the perception of the βM, which is independent of the frequency from which the subject begins to see the illusion. The significant blocks effect and blocks

X days effect on the range and medians and upper limit of the βM might also suggest that subjects "locked in" on the phenomenon across the experimental days and experimental blocks.

IV EXPERIMENT 3
SYNCHRONIZED RHYTHMS IN THE PERCEPTION OF THE SPIRAL AFTER-EFFECT AND THE BETA MOVEMENT

METHOD

Subjects

Sixteen unpaid volunteers aged 17 to 21 years, 11 males and 5 females served as Ss in this experiment. They were completely naive with respect to the experimental hypothesis and were required to avoid consuming any kind of drugs during the day preceding the experimental period.

Apparatus

The SAE apparatus and the βM apparatus were described in the previous experiments. The spiral was rotated in a counterclockwise direction, at a speed of 100 rpm, for 5 sec, each trial. Subjects were given the same instructions with respect to both phenomena, as were those volunteers in the previous experiments.

Procedure and Design

The Ss were randomly divided into two equal groups, which were tested at different times during the 24 hrs. Subjects of Group 1, five males and three females, aged 17 to 20 years, came in pairs to the laboratory at 3 PM, and

immediately received a detailed explanation of the beta movement and the spiral after-effect phenomenon. Then, both phenomena were illustrated until the S consistently observed both illusions. Following the explanation and illustration period, Ss received a practice period until 4 PM, with both illusions. During this period Ss were tested on the SAE twice every 5 min for at least 45 min, except for every fourth trial, during which their lower and upper thresholds of the βM were determined. In the beta trials , Ss were given 2 min of dark adaptation, and were then given 4 ascending and 4 descending trials in alternation. The average time from beginning of the dark adaptation period to the end of the session was approximately 4-6 min. From 4 PM onward, Ss were tested in a similar way until midnight, when they were released from the laboratory. During the inter-trial intervals, Ss were permitted to read, listen to music, or engage in social interaction, which was recorded in behavioral logs. Food, limited to light snacks and soft drinks was supplied ad lib during the experimental period.

The second experimental group, consisting of the other 8 Ss, 6 males and 2 females aged 17 to 21 years, came to the laboratory in pairs at 10 PM, and received similar explanations, illustrations and practice sessions. The practice sessions took approximately 45 min. Then, at about 11 PM, they were fitted with electrodes to record their EEGs and EOGs in a way similar to the Ss in experiments 1 and 2, and

retired at about 11:15 PM. Four of these Ss were awakened from REM sleep and four were awakened from NONREM sleep. All awakenings were made between 6:15 and 8:10 AM.

Upon awakening, Ss were permitted to wash their faces, and then were tested on the spiral after-effect and the beta movement in a way similar to the first group. The experiment lasted eight hours, beginning from the first trial following the awakening. During the experimental period, Ss were permitted to study, listen to music, and engage in social interaction, which was recorded in behavioral logs. Food, limited to light snacks and soft drinks, was supplied ad lib. At the end of the 8 hour period, Ss were released from the laboratory.

RESULTS

With the exception of two Ss from the morning group, whose data had to be removed from the final analysis due to technical difficulties with the equipment, all the Ss successfully completed the 8 hour experimental periods. For each S, within each of the experimental periods, two 24-data point time series were established, the first from the ranges of the beta movement every 20 min, and the second from the durations of the SAE trials, corresponding in times to those of the βM. The latter time series were established by averaging the durations of the illusions on trials preceding and following the βM trials. For example, if a subject was test-

ed on the βM at 10 AM, and then at 10:20 AM, the corresponding SAE durations were taken as the means of the SAE durations at 9:55 AM and 10:05 AM, and 10:15 and 10:25 AM.

The raw data for both variables are presented in Appendix C. The time series for both variables revealed marked linear trends across the 8 hour experimental periods. The F ratios and the significance levels associated with these trends are also presented in Appendix C. To eliminate the linear trends, the time series were detrended by subtracting the predicted values $\hat{Y}_i$ from the observed values Y_i. For presentation purposes, new variables were constructed by adding a constant equal to twice the minimal residual for each of the Ss to each of his residuals. Thus, if m_{ij} represents the minimal residual for subject j, the constant $2m_{ij}$ was added to each of the residuals of S j. Similarly, constants were added to each of the detrended time series of the other Ss. Then, the new variables (r_e) were transformed to log units and displayed against time. The log transformation was justified by the high correlations between the means and the standard deviations of the time series.

Figures 17 to 30 present the time series constructed from log r_e for both variables. Visual observation of the figures reveal that, part of the Ss demonstrated in-phase rhythmicity in the perception of both apparent movements. For instance, all the peaks in the perception of the βM of S JE were concomitant with peaks in the perception of the SAE. Similarly,

Figure 17: SAE durations (empty circles) and βM ranges (filled circles) for S PE for the period 6:30 AM to 2:30 PM.

For explanation of units, see text page 80.

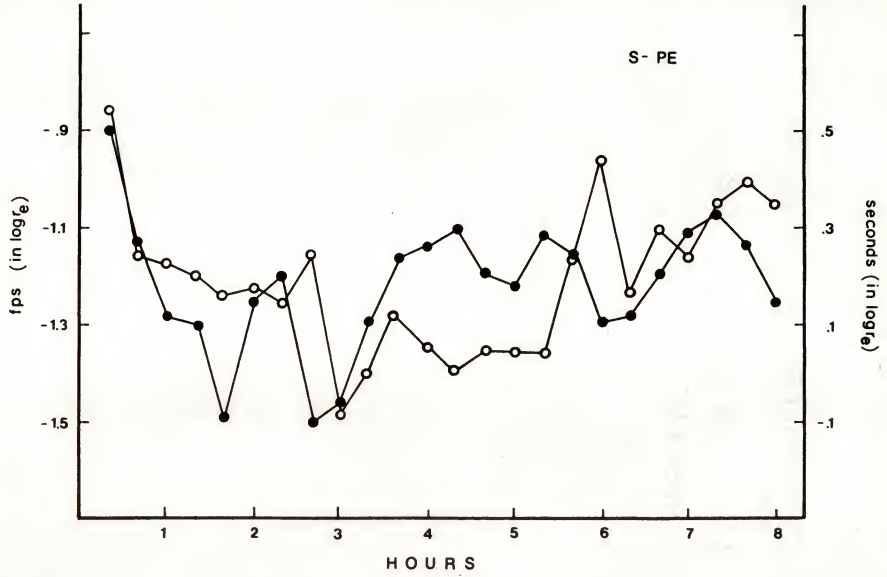

S- PE
-.9
-1.1
-1.3
-1.5
fps (in log e)
.5
.3
.1
-.1
seconds (in log e)
1
2
3
4
5
6
7
8
HOURS

Figure 18: SAE durations (empty circles) and βM ranges (filled circles) for S BR for the period 7:35 AM to 3:35 PM.

seconds (in logr_e)
.8
.6
.4
.2
S – BR
-2
-4
-6
-8
fps (in logr_e)
1
2
3
4
5
6
7
HOURS

Figure 19: SAE durations (empty circles) and βM ranges (filled circles) for S HO for the period 6:15 AM to 2:15 PM.

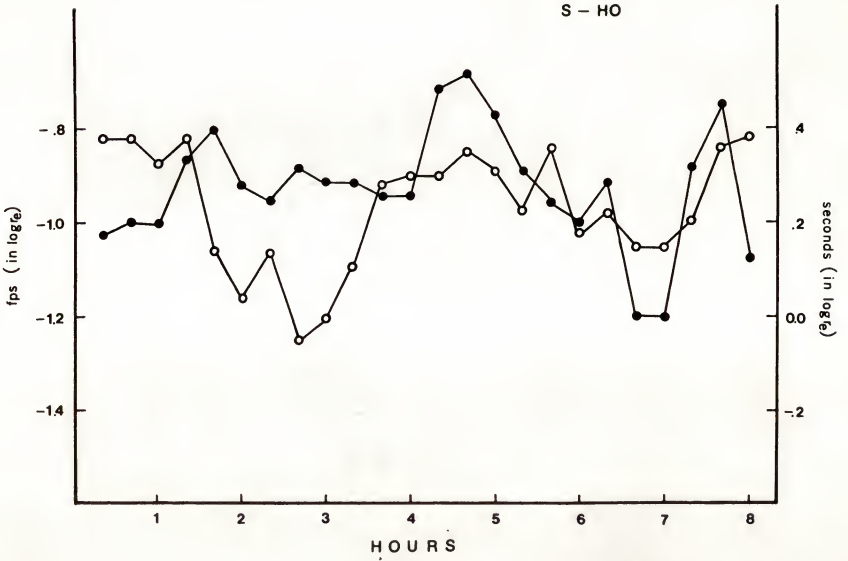

S – HO
fps (in log$_e$)
seconds (in log$_e$)
-.8
-1.0
-1.2
-1.4
.4
.2
0.0
-.2
1
2
3
4
5
6
7
8
HOURS

Figure 20: SAE durations (empty circles) and βM ranges (filled circles) for S PH for the period 8:10 AM to 4:10 PM.

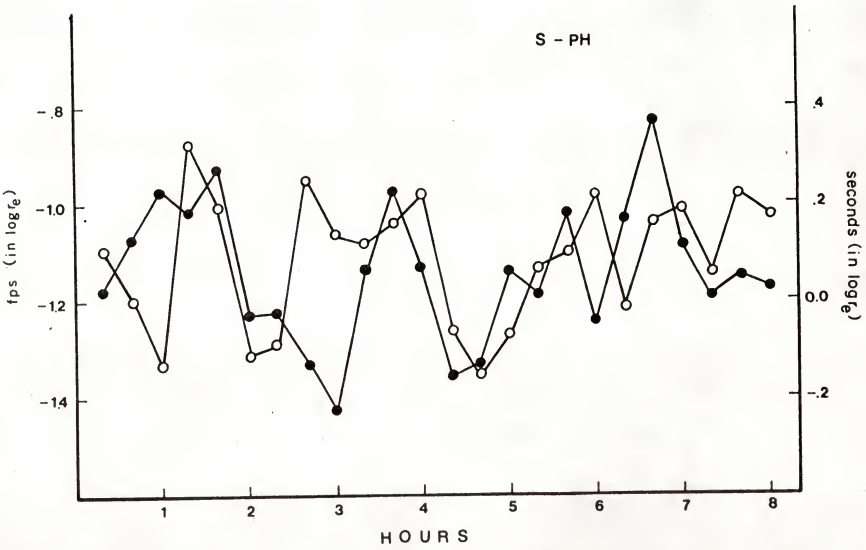

S - PH
-.8
-1.0
-1.2
-1.4
fps (in log$_e$)
.4
.2
0.0
-.2
seconds (in log$_e$)
1
2
3
4
5
6
7
8
HOURS

Figure 21: SAE durations (empty circles) and βM ranges (filled circles) for S DA for the period 7:20 AM and 3:20 PM.

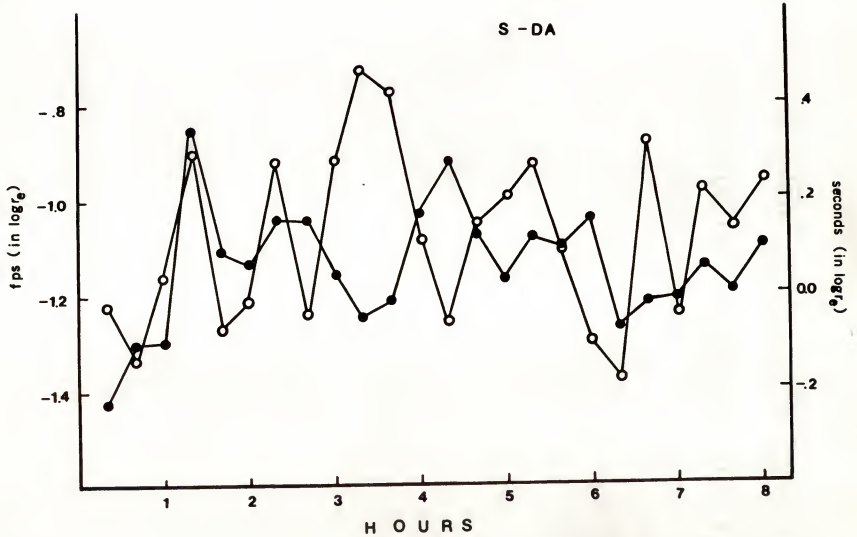

S - DA
fps (in log e)
seconds (in log e)
-.8
-1.0
-1.2
-1.4
.4
.2
0.0
-.2
1
2
3
4
5
6
7
8
HOURS

Figure 22: SAE durations (empty circles) and βM ranges (filled circles) for S BRU for the period 6:30 AM to 2:30 PM.

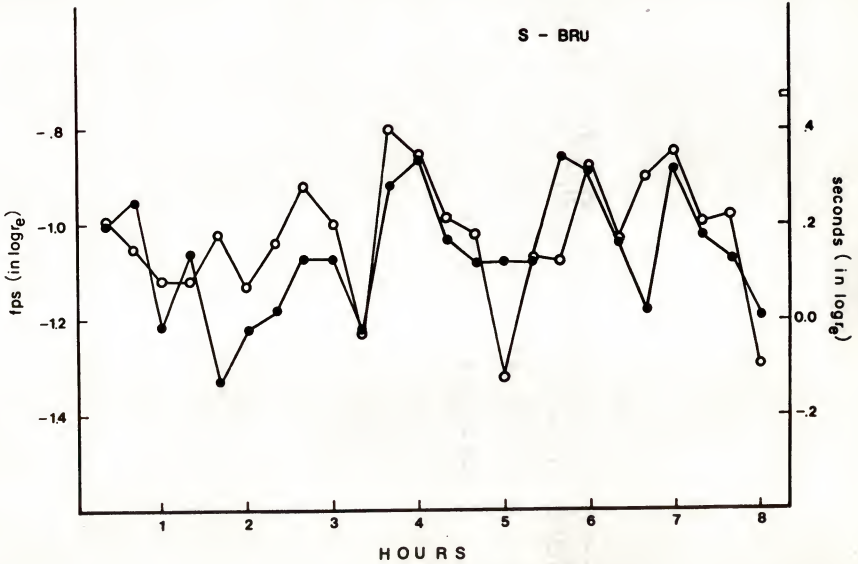

S - BRU
fps (in log$_e$)
-.8
-1.0
-1.2
-1.4
seconds (in log$_e$)
.4
.2
0.0
-.2
1
2
3
4
5
6
7
8
HOURS

Figure 23: SAE durations (empty circles) and βM ranges (filled circles) for S JE for the period 4 PM to 12 midnight.

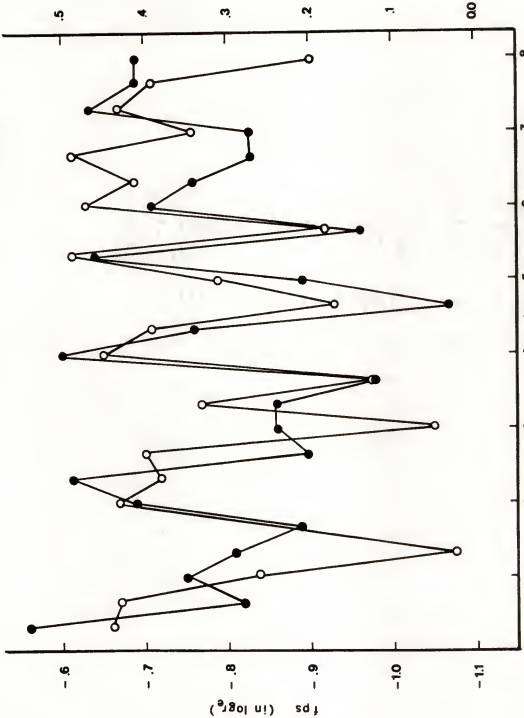

seconds (in logr_e)
.5
.4
.3
.2
.1
.00
S – JE
r_{ps} (in logr_e)
-.6
-.7
-.8
-.9
-1.0
-1.1
1
2
3
4
5
6
7
8
HOURS

Figure 24: SAE durations (empty circles) and βM ranges (filled circles) for S EU for the period 4 PM to 12 midnight.

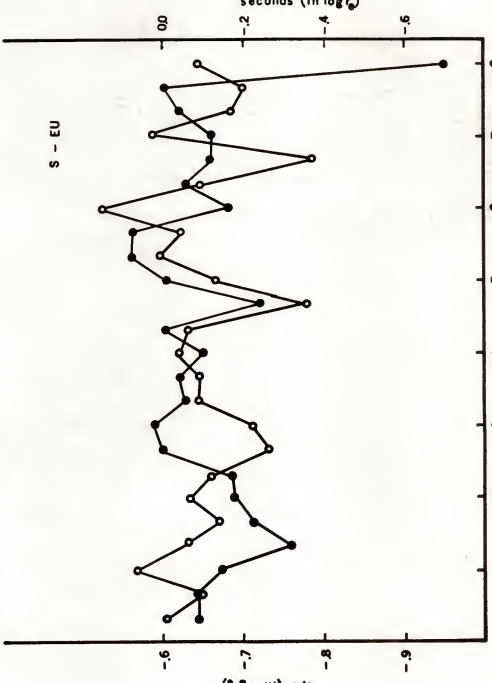

seconds (in log$_e$)
00
-2
-4
-6
S - EU
tps (ln log$_e$ r$_o$)
-6
-7
-8
-9
1
2
3
4
5
6
7
8
HOURS

Figure 25: SAE durations (empty circles) and βM ranges (filled circles) for S AA for the period 4 PM to 12 midnight.

S - AA
tps (in log$_e$)
-.8
-1.0
-1.2
-1.4
seconds (in log$_e$)
.00
-.15
-.30
-.45
1
2
3
4
5
6
7
8
HOURS

Figure 26: SAE durations (empty circles) and βM ranges (filled circles) for S AL for the period 4 PM to 12 midnight.

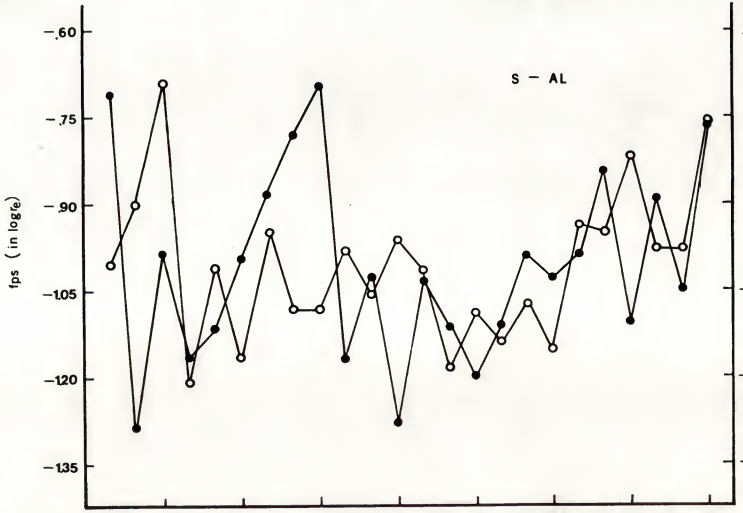

S – AL
fps (in log e)
seconds (in log e)
HOURS
-.60
-.75
-.90
-1.05
-1.20
-1.35
.5
.3
.1
-.1
-.3
-.5
1
2
3
4
5
6
7
8

Figure 27: SAE durations (empty circles) and βM ranges (filled circles) for S IV for the period 4 PM to 12 midnight.

S – IV
seconds (in log r_e)
.4
.2
.00
-.2
fps (in log r_e)
-1.1
-1.2
-1.3
-1.4
1
2
3
4
5
6
7
8
HOURS

Figure 28: SAE durations (empty circles) and βM ranges (filled circles) for S RI for the period 4 PM to 12 midnight.

seconds (in $\log_e$)
.4
.2
0.0
S – RI
-.8
-1.0
-1.2
-1.4
fps (in $\log_e$)
1
2
3
4
5
6
7
8
HOURS

Figure 29: SAE durations (empty circles) and βM ranges (filled circles) for S HE for the period 4 PM to 12 midnight.

S – HE
seconds (in log$_e$)
.6
.4
.2
.00
-.2
-.4
fps (in log$_e$)
-.8
-10
-12
-14
-16
-18
1
2
3
4
5
6
7
8
HOURS

Figure 30: SAE durations (empty circles) and βM ranges (filled circles) for S ST for the period 4 PM to 12 midnight.

seconds (in log$_e$)
.8
.6
.4
.2
S − ST
HOURS
1
2
3
4
5
6
7
8
tps (in log$_e$)
-.4
-.6
-.8
-1.0

periods of narrow ranges in the perception of the βM were concomitant with periods of short durations of the SAE. Close resemblance between the SAE and the βM time series was evinced by Ss BRU, RI, PH and IV. For these Ss, peaks and troughs in the perception of the two illusions occurred at the same times, or no more than 10 min apart. Other Ss demonstrated intermediate degrees of resemblance between the two time series. For these Ss, only some of the peaks and troughs in the two time series occurred at the same times or at short intervals apart. Some of the Ss showed no synchronized relationship at all. For example, S DA although revealed cyclicity in the perception of the βM, except for the first two peaks, none of the rest of his βM peaks were concomitant with his SAE peaks.

Periodicities in Perception

According to the experimental hypothesis, it was expected that Ss would manifest ultradian rhythms in the perception of both illusions. Time series analyses techniques were utilized in order to determine hidden periodicities in the perception of the SAE and the βM. First, the autocorrelation functions were calculated for the detrended time series, up to a lag of 220 min. Then, the autocorrelation functions were transformed to power spectral estimates, using the Hamming window (Jenkins and Watts, 1968). The number of spectral frequencies for which the power was estimated was determined by the length of the time series and the number of data points. Thus, the power

spectrum was estimated for the frequencies: 0.002174 cycle/min, 0.004348 cycle/min, 0.006522 cycle/min, 0.008696 cycle/min, 0.01087 cycle/min, 0.013043 cycle/min, 0.0152 cycle/min, 0.0195 cycle/min, 0.02173 cycle/min, 0.0239 cycle/min, and 0.025 cycle/min. Four of these frequencies are in the approximate range defined by Kripke (1972) as the ultradian range (70 to 150 min): 0.006522 cycle/min, 0.008696 cycle/min, 0.01087 cycle/min, and 0.013043 cycle/min. Converting these frequencies into reciprocals reveals: 153.32 min/cycle, 114.99 min/cycle, 91.99 min/cycle, and 76.66 min/cycle.

It is important to note that the power estimated for a particular frequency is actually estimated for a range around this frequency. This range, or "bandwidth", is determined by adding and substructing 1/2T from the spectral frequency, when T is the length of the record, which is 440 min in the present experiment. Hence, the power estimated for the frequency 114.99 min/cycle, actually represents the power for the bandwidth 102.218 to 131.42 min/cycle.

Following the power transformation, the spectral peaks were determined. Two spectral peaks were defined: the first one, defined as the highest spectral intensity preceded as well as followed lower spectral intensities, and the second one, defined as the second highest spectral intensity preceded as well as followed lower spectral intensities. The peak frequencies (the frequencies associated with the spectral peaks) are presented in Table 6.

For the SAE time series, five out of the six Ss of the morning group revealed first or second frequency peaks within the ultradian range (70-150 min). All the Ss, tested during the morning sessions, revealed first or second ultradian peaks for the βM time series. Subjects DA and PH manifested identical first peaks for the βM and the SAE time series, and Ss PE and BR manifested identical second peaks for the two variables. Subject BRU had the first spectral peak in the βM time series identical to the second peak in the SAE time series.

Six out of the eight Ss of the afternoon group revealed first or second peaks within the ultradian range for the SAE time series, and seven Ss revealed similar peaks for the βM time series. Only one S, EU, demonstrated identical first and second peaks for the two time series; Ss HE and JE demonstrated identical second peaks, and Ss AA and ST demonstrated non-identical peaks. The median peak frequency for the SAE and the βM time series for the morning group was 92 min, and 115 min for the afternoon group.

To determine whether the distribution of power across the spectral frequencies represented a random distribution, the coefficient of concordance suggested by Kendall (1948) was utilized. Significant concordance coefficients were obtained for both the SAE time series ($W = .2367$, $\chi^2 = 33.14$, $df = 10$, $p < .005$), and for the βM time series ($W = .2349$, $\chi^2 = 32.886$, $df = 10$, $p < .005$). Thus, it could be concluded that the relatively large number of peak frequencies within the ultradian

TABLE 6

Spiral After-Effect and Beta Movement Peak Frequencies in Min/Cycle for Each Subject

	Spiral After-Effect		Beta Movement	
Subject	First Peak	Second Peak	First Peak	Second Peak
HO	229.93	65.78	229.93	76.66*
PE	459.98	115*	229.93	115*
BRU	229.93	92*	92*	-
DA	92*	65.78	92*	229.93
BR	229.93	76.66*	229.93	76.66*
PH	153.32*	76.66*	153.32*	57.50
RI	229.93	-	115*	-
EU	153.32*	57.50	153.32*	76.66*
ST	115*	57.50	229.93	92*
JE	65.78	115*	65.78	115*
AA	153.32*	51.11	92*	51.11
AL	229.93	92*	229.93	51.11
IV	229.93	51.11	57.50	153.32
HE	51.11	115*	459.98	115*

* Peak frequencies marked with a star are within the approximate ultradian range defined by Kripke (1972).

range were not randomly determined, but reflected a genuine tendency to an ultradian modulation of the perception of the two apparent movements.

In addition to the Kendall Concordance coefficient, the Binomial theorem was also applied to the data to evaluate the probability of random distribution of power across the spectral frequencies (Kripke, 1972). Eleven out of the twenty-eight first peak frequencies fell into one of the three frequencies: 153.32 min/cycle, 115 min/cycle and 92 min/cycle. The probability of such an event being random was found to be less than .04.

Phase Relationship Between the SAE and the βM Time Series

To assess the phase relationship between each pair of time series for each S, the cross-correlation function between the two time series was calculated up to a lag of 220 min. Then, the cross-correlation coefficients were transformed to Z-scores and were pooled across all Ss who manifested cyclicity in both variables. The pooled cross-correlation functions are presented in Figure 31. Although the cross-correlation coefficients were rather small, the comparatively high coefficients at lags 0, +120, -80, and -200 min, suggest in-phase relationship between the SAE and the βM time series for these lags. The high coefficients for the lags 120 and -80, which suggest common periodicity for the βM and the SAE time series of approximately 80 to 120 min, agree with the

results of the spectral analysis, which indicated a significant number of spectral peaks within the range 153 to 76 min, with medians of 92 and 115 min.

Eliminating the results of four Ss who revealed non-identical peak frequencies for the two variables resulted in identical pooled cross-correlation function to the one previously observed, but with enhanced coefficients (Figure 32).

REM and NONREM Awakenings

In light of the results of the first experiment, which demonstrated differential phasing of the ultradian rhythm, and the results of the second experiment, which demonstrated differential response to the beta movement following awakening from REM and NONREM sleep, it was decided to determine the phase relationship of the βM and the SAE time series for Ss awakened from the two phases of sleep.

Figure 33 presents the pooled βM ranges and the SAE durations for the first six trials (120 min), for Ss awakened from REM sleep (N=2) and NONREM sleep (N=4) in the morning group. The averaged βM ranges indicate opposite trends for Ss awakened from the two phases of sleep. Subjects awakened from REM sleep reached a trough in the range of the βM approximately 80-100 min following the awakening, while Ss awakened from NONREM sleep reached a peak in perception at approximately the same time. The averaged SAE durations for the same period did not manifest similar trends; however, Ss awakened from

Figure 31: Pooled cross-correlation function between the spiral after-effect and the beta movement time series for Ss who demonstrated ultradian periodicities in both measurements.

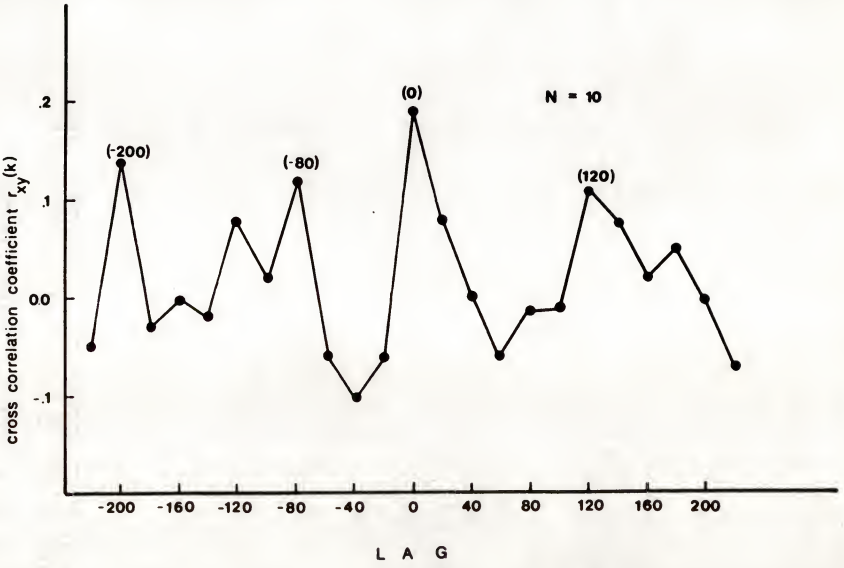
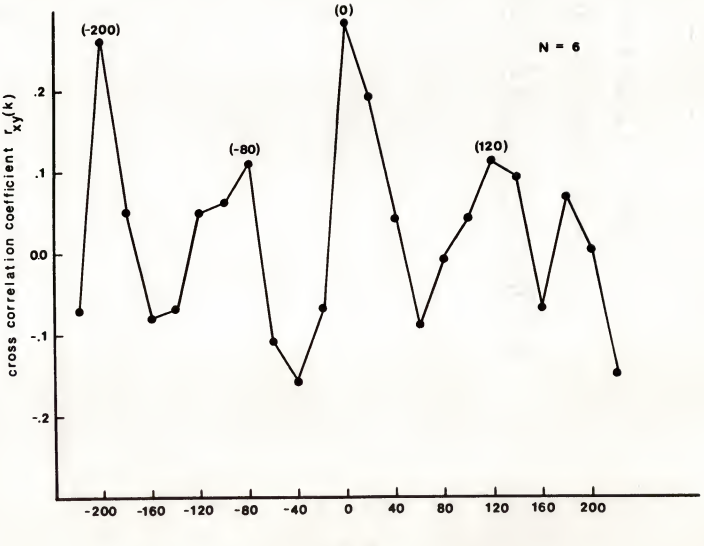

cross correlation coefficient $r_{xy}(k)$
.2
.1
0.0
-.1
(-200)
(-80)
(0)
(120)
N = 10
-200
-160
-120
-80
-40
0
40
80
120
160
200
L A G

Figure 32: Pooled cross-correlation function between the spiral after-effect and the beta movement time series for Ss who demonstrated identical ultradian periodicities in both measurements.


(-200)
(0)
N = 6
(-80)
(120)
cross correlation coefficient $r_{xy}(k)$
.2
.1
0.0
-.1
-.2
-200 -160 -120 -80 -40 0 40 80 120 160 200
L A G

NONREM sleep demonstrated elevation in the duration of the illusion 80 min following the awakening, similar to the peak manifested for the ranges of the βM.

Due to the different periodicities demonstrated by the morning Ss, it was not possible to average the REM and NONREM time series for the entire length of the experimental period. Thus, in order to explore further the phase relationship between the REM and NONREM time series, the cross-correlation method was utilized. First, the βM time series of those Ss awakened from NONREM sleep who demonstrated first or second peak frequencies within the ultradian range were cross-correlated with the corresponding time series of the two Ss awakened from REM sleep, and then a pooled cross-correlation function was established based on the 8 functions (left panel, Figure 34). Second, the NONREM time series were cross-correlated with each other, and pooled across all pairs (right panel, Figure 34); and third, the βM time series of the two Ss awakened from REM sleep were cross-correlated (Figure 35). The cross-correlation coefficients were transformed to Z-scores before averaging. The corresponding REM-NONREM, NONREM-NONREM, and REM-REM cross-correlation functions for the SAE time series are presented in Figures 36 and 37.

The relatively high cross-correlation coefficients for both the SAE and the βM NONREM-NONREM functions at lag 0 (beta movement) and 20 (SAE) suggest that the time series for Ss awakened from NONREM sleep were in phase with respect to

Figure 33: Spiral after-effect durations and beta movement ranges of the first 6 trials averaged across Ss awakened from REM sleep (N=2), and Ss awakened from NONREM sleep (N=4).

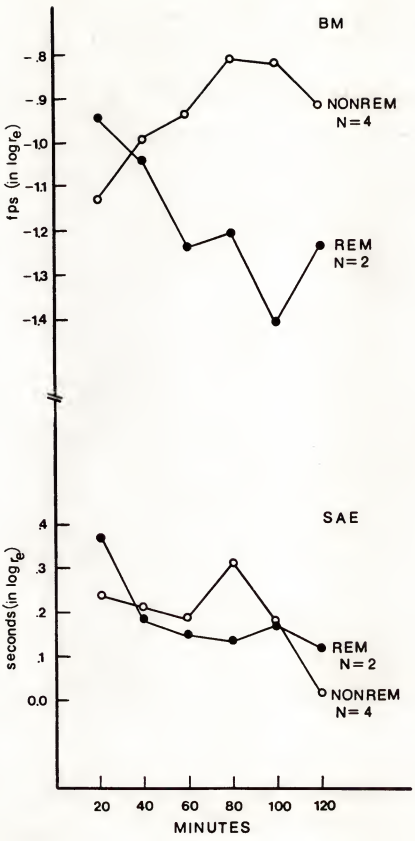

BM
-.8
-.9
-1.0
-1.1
-1.2
-1.3
-1.4
fps (in log$_e$)
NONREM
N=4
REM
N=2
SAE
.4
.3
.2
.1
0.0
seconds (in log$_e$)
REM
N=2
NONREM
N=4
20
40
60
80
100
120
MINUTES

Figure 34: Pooled cross-correlation functions between the beta movement time series of Ss awakened from REM sleep and NONREM sleep (left panel), and the beta movement time series of Ss awakened from NONREM sleep (right panel).

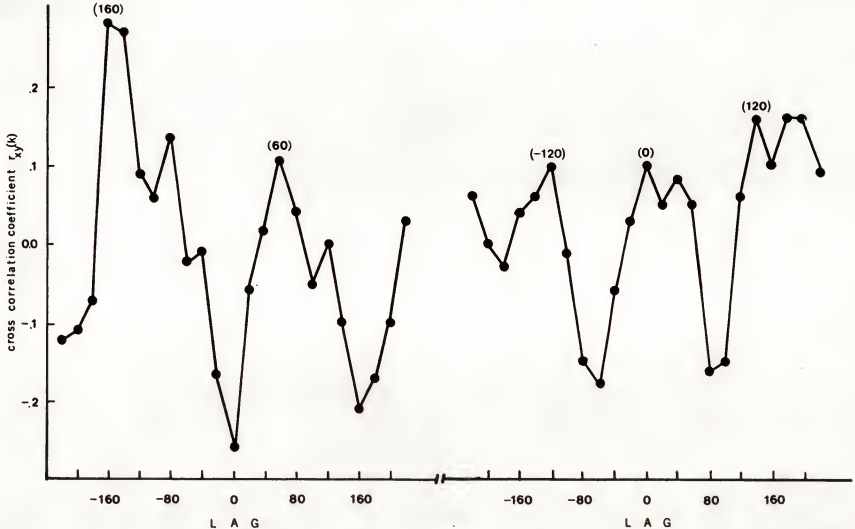

(160)
(60)
(−120)
(0)
(120)
.2
.1
.00
−.1
−.2
cross correlation coefficient $r_{xy}(k)$
−160
−80
0
80
160
L A G
−160
−80
0
80
160
L A G

Figure 35: Cross-correlation function between the beta movement time series of the two Ss awakened from REM sleep.

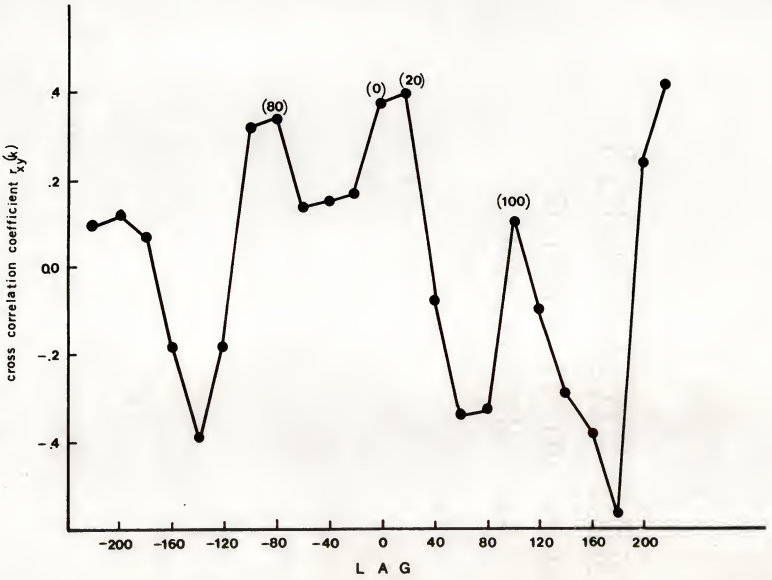

cross correlation coefficient $r_{xy}(k)$
.4
.2
0.0
-.2
-.4
(80)
(0)
(20)
(100)
-200
-160
-120
-80
-40
0
40
80
120
160
200
L A G

Figure 36: Pooled cross-correlation functions between the spiral after-effect time series of Ss awakened from REM sleep and NONREM sleep (left panel), and the spiral after-effect time series of Ss awakened from NONREM sleep (right panel).

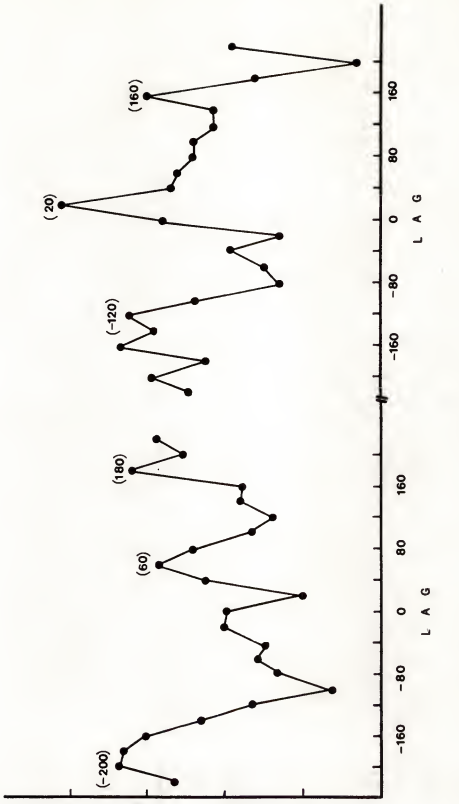
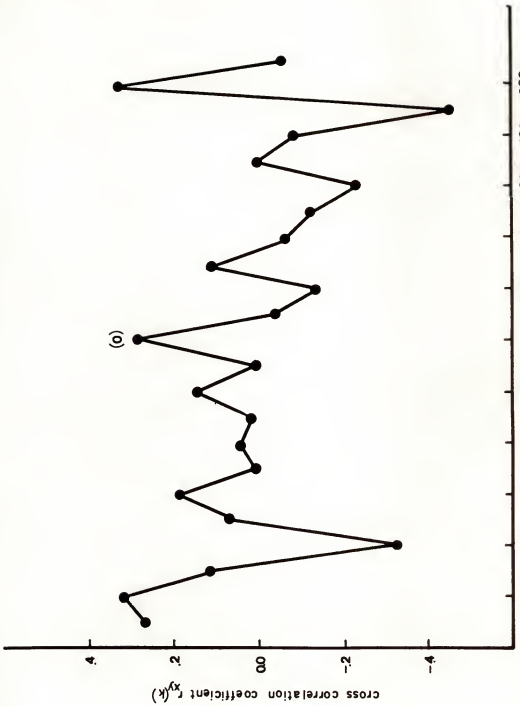

cross correlation coefficient $r_{xy}(k)$
.4
.2
0.0
-.2
(-200)
(60)
(180)
(-120)
(20)
(160)
-160
-80
0
80
160
L A G

Figure 37: Cross-correlation function between the spiral after-effect time series of the two Ss awakened from REM sleep.


cross correlation coefficient $r_{xy}(k)$
.4
.2
.00
-.2
-.4
-200
-160
-120
-80
-40
0
40
80
120
160
200
L A G
(0)

each other. The high coefficients for lags -120 and +120 min for the βM, and for lags -120 and 160 min for the SAE, suggest a common periodicity for the time series in this range. Although based on only two time series, the cross-correlation functions for the REM-REM time series are similar to the NONREM-NONREM time series. The relatively high coefficients at lags 0 and 20 (βM) and 0 (SAE), suggest that the two cycles were in phase. On the other hand, the NONREM-REM functions of both the βM and the SAE time series revealed zero or negative coefficients for the range +40 to -40 min, indicating phase differences between the REM and NONREM time series. The first peak in both the βM and the SAE functions was at a lag of 60 min, which suggests a phase difference of approximately this order between the time series of Ss awakened from REM sleep and NONREM sleep.

In summary, the results of the third experiment show that:
1) Ten of 14 subjects tested for 8 hours on the SAE and on the βM demonstrated 70 to 150 min ultradian rhythms in both illusions.
2) Subjects tested during the morning hours had shorter median periodicities for both the SAE and the βM time series than Ss tested during evening hours.
3) The cross-correlation functions between the SAE and the βM time series provide suggestive evidence that Ss, who demonstrated ultradian periodicities in both apparent movements, tended to have the two cycles in-phase. This was enhanced for Ss who demonstrated identical periodicities for both apparent

movements.

4) Subjects awakened from REM sleep demonstrated opposite trends in response during the first 6 trials than Ss awakened from NONREM sleep. The differential trends were more observable for the βM ranges.

5) An approximate 60 min phase difference was observed between the βM and SAE time series of Ss awakened from REM and NONREM sleep. The βM and the SAE time series of Ss awakened from the same phase of sleep were found to be in phase.

DISCUSSION

The results of experiment 3 support earlier reports on the existence of ultradian rhythms in the perception of the SAE (Lavie, Lord and Frank, 1974; Lavie, Levy and Coolidge, 1974), and substantiate the existence of such rhythms in the perception of the βM. In spite of the fact that each of the power density functions was associated with only 4 degrees of freedom (Blackman and Tukey, 1958), the highly significant concordance coefficients indicated an underlying ultradian rhythmicity in the perception of both illusions.

As reported earlier, the periodicity in the perception of the SAE and the βM was not demonstrated by all subjects. Four subjects, one of the morning group and three of the afternoon group, did not manifest spectral peaks within the ultradian range for at least one variable. Although no immediate explana-

tion can be offered for the observed individual differences in the manifestation of the rhythmicity in perception, a suggestive explanation can be proposed, after comparing the manifested cyclicity to subjects' levels of activity, as was recorded in the behavioral logs during the experimental periods. Subjects who demonstrated the highest levels of activity during the experimental periods, e.g., who spent most of the time being actively engaged in social interaction with the experimenters or the other subject, demonstrated the least detectable rhythms in perception. On the other hand, subjects who spent most of the inter-trials alone, reading, listening to music, or doing just nothing, had the most easily observable ultradian rhythms. It is interesting to note that Blake (1971) reported that diurnal effects on performance of signal detection task can be masked by giving the subjects knowledge of their results, or by introduction of high levels of noise into the experimental environment. He speculated that both variables increase the subject's level of arousal and therefore masked the influence of diurnal effects on the performance.

In most of the studies demonstrating ultradian rhythmicity in behavioral indices, some type of isolation paradigm was utilized. This was done in order to minimize environmental influences on the endogenous biorhythmicity. Thus, it may be concluded that for some of the Ss the ultradian rhythmicity was masked by the high levels of social activity, which were not limited in the present experiment.

The median morning periodicity for both the SAE and the βM time series (93 min) was shorter than the corresponding medians for the afternoon time series (115 min). This agrees with the accumulated data on the circadian modulation of the ultradian rhythmicity presented earlier.

The comparatively high cross-correlation coefficients for zero lag between the βM and the SAE time series suggests that the two ultradian rhythms were in-phase across the 8 hour experimental periods. Periods of wide ranges of the βM were concomitant with periods of longer durations of the SAE. The in-phase rhythmicity in the perception of the two apparent movements supports the view that a common oscillator is responsible for the approximately 90 to 110 min ultradian rhythms detected in signal detection (Globus et al., 1971), oral activity (Friedman and Fisher, 1967; Oswald et al., 1970), general activity level (Globus et al., 1973), daydreaming (Kripke and Sonnenshein, 1973), and physiological measurements (Orr, Hoffman, and Hegge, 1973).

Only some of the Ss demonstrated a close phase relationship between the SAE and the βM time series. A variety of reasons may be responsible for the dissociation of the two rhythms for some of the Ss. For instance, the SAE was sampled every 5 min, while the range of the βM was sampled every 20 min. Thus, it is possible that the limited sampling rate of the βM ranges did not reflect the true peaks and troughs in perception, which may have occurred between the sampling points. Also, it is possible that the accumulated fatigue, boredom, etc., and

the level of subject's activity, differentially influenced the perception of the two apparent movements with respect to the manifestation of the ultradian rhythmicity. One cannot exclude the possibility that the two cortical mechanisms responsible for the SAE and the βM were differentially influenced by the rhythm itself.

In agreement with earlier results, and in particular with those presented in the first and second experiments, are the differential trends in the perception of the βM manifested by Ss awakened from REM and NONREM sleep. As observed in the first experiment for the trends in the perception of the SAE, Ss in the present experiment, when awakened from NONREM sleep, reached a peak in perception approximately 80 min following the awakening, while Ss awakened from REM sleep reached a trough at approximately the same time. This provides additional support for the suggestion proposed in the discussion section of Experiment 1, that the sleep and waking fragments of the ultradian rhythm are continuous. The similarity in the initial phase of response to the SAE of the REM and NONREM time series also agrees with the results of the first experiment, which indicated no phase differences between the four awakening conditions. However, the small elevation in the perception of the SAE observed for the NONREM time series is also noted in the peaking of the βM time series.

The phase relationship between the REM and NONREM time series was also supported by the results of the cross-correlation analysis. This suggested a phase difference of approximately 60 min between the REM and NONREM time series, while

indicating that the REM time series and the NONREM time series were in phase for both measurements.

As concluded in the discussion section of the second experiment, the results of the present experiment further support the role of cortical mechanisms in the perception of the βM. It is also suggested that more attention needs to be paid to the temporal characteristics of experiments utilizing the ranges of the βM as a dependent variable. Inadequate control of the phase of the ultradian rhythm might introduce a potent uncontrolled source of variability into the results.

V GENERAL DISCUSSION

The study of the infrastructure of sleep, triggered by the discovery of the REM sleep by Aserinsky and Kleitman (1953), has since covered almost every possible aspect of sleep. Inherent to most of the studies conducted so far is the assumption that the REM-NONREM cycle is an intrinsic part of the sleep process, and is unique to this state of awareness. The recently accumulated data on the existence of waking ultradian rhythms of the same periodicity as that of the REM-NONREM cycle (Friedman and Fisher, 1967; Lavie, Levy and Coolidge, 1974; Lavie, Lord and Frank, 1974 and others), and the results of the present dissertation which confirmed these earlier reports, suggest that the REM-NONREM cycle is only the nightly manifestation of a broader biological rhythm operating across both sleep and wakefulness.

The results of the first experiment, which demonstrated earlier first peak latencies for subjects awakened from NONREM sleep, than for subjects awakened from REM sleep, and the results of the third experiment, which demonstrated that the SAE and ßM cycles of subjects awakened from REM sleep were out of phase with respect to the corresponding cycles of subjects awakened from NONREM sleep, strongly support the hypothesis that the REM-NONREM cycle and the waking ultradian rhythms are

continuous across the transition from sleep to waking. Such contiuity between the REM-NONREM cycle and performance cycle in cats was noted earlier by Sterman (1972).

Although the present results do not permit extending the continuation hypothesis to the opposite pole of the behavioral continuum, i.e., to the transitional period from wakefulness to sleep, it seems that the reported high variability of the first REM period latencies (Agnew and Webb, 1973) can be explained by such an assumption. However, as noted earlier, the fact that a minimum amount of NONREM sleep must elapse before normal subjects retiring at the "habitual sleep hours," can reach their first REM period suggests that the transition from wakefulness to sleep temporarily interrupts the course of the ultradian rhythm. The sensitivity of the durations of the SAE and the ranges of the βM to the phase of the ultradian rhythm will enable future research to exlore the phase relationship between the two rhythms across the transition from wakefulness to sleep.

It is interesting to note in this context that patients suffering from narcolepsy reportedly have immediate sleep-onset REM periods (Rechtschaffen et al., 1963). This, and the fact that the physiological characteristics of narcolepsy attacks closely resemble the physiological characteristics of the REM sleep (Dement et al., 1966) might indicate that narcolepsy involves some kind of abnormality of the ultradian rhythmicity.

The data accumulated on the REM-NONREM cycle have pointed out the nonstationary frequency and amplitude characteristics of the REM-NONREM cycle. As noted earlier, there are marked differences in the first REM period latencies, the length of the REM-NONREM cycle, and the amount of REM sleep, between early and late hours of the night (Taub and Berger, 1973; Agnew and Webb, 1973). Similar differences were observed by Foret (1973) between sleep periods during the morning hours and the afternoon hours. These differences suggest a circadian modulation of the REM-NONREM cycle which "potentiates" the cycle around the early morning hours. In the first experiment of this dissertation, the fact that the late group reached the first peak in perception sooner than the early group, under all four awakening conditions, provides suggestive evidence that a similar circadian modulation is also influencing the waking ultradian rhythms. This assumption was further supported by the fact that in the third experiment, subjects tested from early morning hours until early afternoon hours revealed shorter SAE and βM median periodicities than subjects tested from 4 PM to 12 midnight. However, sex differences between the groups of the first experiment might account for the observed differences between the groups. Although this possibility seems remote, the results should be replicated before being considered conclusive.

It is worth noting that the course of the temperature cycle across the 24 hours seems to parallel the changes in the frequency of the waking ultradian rhythms. While the nadir

of the temperature cycle around the early morning hours is associated with the shortest first REM period latencies, the highest amounts of REM sleep, and with the shortest REM-NONREM cycles, the peak of the temperature cycle around afternoon hours is associated with the longest REM period latencies, the smallest amounts of REM sleep and with the longest REM-NONREM cycles. This interesting relationship might suggest a possible meaningful relationship between the two biorhythms, or might suggest a common circadian oscillator for both rhythms. The high variability in the REM-NONREM cyclicity, and in the temperature cycle, might lend itself to further investigation of such possible relationships between the rhythms.

The results of the third experiment indicated that for some of the Ss, the ultradian rhythms in the perception of the SAE and the BM were synchronized during the experimental periods. This suggests that both rhythms were driven by a common oscillator. Since most of the studies demonstrating rhythmicity have explored only one variable (Friedman and Fisher, 1967; Oswald et al., 1970; Globus et al., 1971; Globus et al., 1973; Lavie, Lord and Frank, 1974; Lavie, Levy and Coolidge, 1974), they could not have demonstrated synchronized rhythmicities. Only two studies described ultradian rhythmicity in more than one variable. Kripke (1972) tested several physiological and behavioral variables simultaneously, and reported a 70 to 150 min rhythm in several physiological and behavioral measurements. Also, Orr, Hoffman and Hegge (1973) reported

"Clear evidence of a 90-minute rhythm in both the heart-rate and behavioral parameters"(pp. 190). The behavioral parameters cited were measurements of continuous signal detection task. However, in neither of these studies was the phase relationship between the oscillating variables determined.

Although the results of the third experiment demonstrated synchronized ultradian rhythms for one special type of perceptual process, i.e., the perception of apparent movements, this might suggest that the various behavioral and physiological parameters known to describe an ultradian rhythm during the waking state may be synchronized and driven by a common oscillator. Specifically, under this assumption it would be expected that waking periods of long SAE durations and wide βM ranges would also be associated with intense daydreaming, intense oral activity, improved signal detection performance, increased body movements and high values for physiological indices of arousal, or activation.

The apparent existence of such synchronized periodic changes in the intensity of various behaviors, and periodic changes in the direction of behaviors, accompanied by physiological activation, might suggest that the ultradian biorhythm can be viewed as an endogenous "activation" cycle, and the data on this cycle can be incorporated into the framework of the "arousal" and "activation" concepts. According to Duffy: "Activation refers, not to the overt activity of the organism, but to the release of energy into various internal physiological systems, in preparation for overt activity.... Activation is a physio-

logical intervening variable controlled by the neurohumoral system" (1972, pp. 578). This definition agrees with the current knowledge on the ultradian rhythms, which can be viewed as periodic changes in "activation levels." Furthermore, several researchers reported on the relationship between the sleep and waking ultradian rhythms and the neurohumoral systems (Mandell et al., 1966). However, in contrast to Duffy's (1972) views that "activation" is in a state of constant variations, the present data indicate a regular and controlled rhythm in the organism's level of activation.

Hence, it seems necessary to re-evaluate some aspects of the "activation" and "arousal" concepts in order to reconcile them with the new data. The fact that there are at least two arousal systems, a tonic one which regularly changes, and a phasic one, superimposed on the tonic one, which can occasionally override its effects, might suggest the existence of at least two neurophysiological systems which control the organism's level of "activation." Such an argument was forwarded earlier by Ruttenberg (1968), who hypothesized the existence of two arousal mechanisms, the reticular formation and the limbic system, and by Feldman and Waller (1962), who stressed the role of the hypothalamus in regulating arousal states.

In addition, the results of the present dissertation have some important implications in the area of methodology and experimentation in psychology. Data on the temporal characteristics of experiments are rare in the experimental psychology

literature. The present results indicate that an inadequate control of the phase of the ultradian rhythm may introduce an additional uncontrolled source of variability in experiments utilizing the ranges of the beta movement and the duration of the SAE as dependent variables. For instance, Andersson (1969) tested subjects twice, two weeks apart on the SAE, and defined their personality styles according to the change in the slopes of their responses to the SAE, across 30 trials. A more simple and more plausible explanation for the observed differential slopes across days would be that subjects were tested during different phases of their ultradian waking cycle each day, and so the results would be inconclusive. Thus, it seems necessary, that when using variables that are found to be sensitive to the course of the ultradian rhythm, one has to verify the phase of the rhythm, or to eliminate its influence, for example, by inducing a high level of arousal, or motivation, in order to avoid introducing uncontrolled variability into the results.

Some Speculations on the Nature of the Ultradian Rhythms

Much additional research needs to be done before satisfactory answers are available to most of the more specific questions regarding ultradian rhythms. For example, research into the neurophysiological aspects of the ultradian rhythms is practically non-existent. However, the available data on the physiological and behavioral properties of the REM and NONREM sleep, and the various behaviors susceptible to the phase of

the waking ultradian rhythm, permit some tentative speculations on the relationship between the REM-NONREM cycle and the ultradian biorhythm, and the roles of the ultradian rhythm. The following discussion is directly related to these matters.

Although it was consistently suggested that both the REM-NONREM cycle and the waking ultradian rhythms are fragments of the same biorhythm, there are some indications that the REM sleep per se is not an essential part of the ultradian rhythm, but may represent a confluence of physiological phenomena that oscillate in phase during sleep. Dement (1973) wrote that perhaps the REM state is "nothing more than temporal confluence of at least three separate processes which can easily operate, function, or discharge, outside the REM periods and independently of one another" (pp. 53, his emphasis). According to Dement, the three separate processes are the tonic inhibition, CNS arousal and the phasic activity, which are all manifest during the REM period.

The dissociation of the phasic events and the tonic inhibition from the REM periods under REM deprivation conditions lends support to Dement's views. The PGO spikes, the most prominent phasic events of the REM sleep in the cat, can be shifted into NONREM sleep, or to the waking state, under the REM deprivation conditions (Dement, 1966). Similarly, the gap between the EMG suppression and the EEG activation, which in normal subjects is a few seconds, is considerably enlarged under long REM deprivation in humans (Dement, 1965). Another phasic component of the REM sleep which can be easily dissociated from

the REM sleep is the penile erections, which usually accompany REM sleep, but begin to occur during NONREM sleep if subjects are REM deprived (Karacan and Goodencugh, 1966). Actually, although the REM-NONREM cycle is considered to be a regular 90 min rhythm, it is far from being a regular cycle, and a considerable amount of variability was noted within one night of sleep and across nights (Moses et al., 1972). In their earliest report, Dement and Kleitman (1957) observed irregularities in the appearance of the first REM stage. Sometimes, in spite of the decreasing amplitude of the EEG at the expected times of the REM periods, no REM stage, as defined by the appearance of the phasic eye movements, was evident.

Thus, it can be speculated that the ultradian biorhythm operating across both sleep and wakefulness reflects only one of the three components of the REM sleep - CNS arousal, while the tonic inhibition and the phasic events are additional components that reach the sleep fragment of the cycle during periods of peak activity.

Viewing the REM periods as multiple phenomena, consisting of at least the three separate processes above, may help explain one of the apparent paradoxes posed by the existing 90 min ultradian rhythm theory. The assumption that the REM state continues into waking, as was reported by Lavie and Giora (1973), Lavie (1974), and others, contradicts the well documented REM rebound phenomena, following nights of REM deprivation (Dement, 1960). If the REM state continues into waking,

why does the organism compensate for the loss of REM sleep? It may be that the rebound effects regain only some phasic components of the REM period, and not the REM sleep per se. Dement et al. (1970) reported that the supression of the PGO spikes was better related to spikes rebound than the stage REM supression was to stage REM rebound. This led Dement et al. to suggest: "...that the crucial factor in the so called REM sleep deprivation-compensation phenomenon might be the deprivation of phasic events. Post-deprivation increase in total REM time might be regarded as a response to an accumulated 'need' for phasic events, and not as a response to the loss of REM sleep per se" (pp. 102). It is also important to note that marked individual differences have been observed with respect to the REM rebound phenomenon. Of the seven subjects who completed Dement's original study (1960) of REM deprivation, five showed varying amounts of rebound over their base data, and two showed none. Cartwright et al. (1967) also reported that "The more dream like experiences which took place in the absence of the usual amount of REM state, the less was the need for additional REM sleep" (pp. 301). Similar phenomena were noted by Dement et al. (1971) for actively ill schizophrenics who tended to hallucinate during the day. Thus, the REM rebound effects may be limited to the rebound of the additional components of the REM sleep which are not intrinsic parts of the 90 min ultradian biorhythm.

The peculiar characteristics of the REM sleep have led many researchers to attribute to the REM stage such vital roles

as: maintaining the integrity of voluntary conjugate eye movements during extended periods of NONREM sleep (Berger, 1969), increasing the cortical tonus and readiness to respond following loss of tonus in NONREM sleep (Ephron and Carrington, 1966) and processing, evaluating, and storing information which has been accumulated during the day (Dewan, 1969). Snyder and Scott (1972) went even further to suggest that REM sleep is "third basic organismic state," different from NONREM sleep and wakefulness. Although the possibility cannot be excluded, that the ultradian 90 min biorhythm and the REM-NONREM sleep periods serve different functions, it seems that these theories should be re-evaluated in the light of the new data.

For instance, Berger (1969), who postulated that the function of REM sleep is to innervate the occulomotor system during extended periods of NONREM sleep, claimed support for his theory by reporting that binocular depth perception was more accurate at the "offsets of REM periods than at their onsets" (Berger and Scott, 1971) and that occular imbalances were of greater magnitude at the onset of REM periods than at the end of the REM periods (Berger and Walker, 1972). In the second study, Berger and Walker claimed that arousal differences between the two awakenings could not be responsible for the reported results since no differences were observed in the amount of alpha activity between the two awakenings. However, the results of Lavie and Giora (1973), Lavie (1974), and the results of the present dissertation, all demonstrate changes in visual perceptual processes, unrelated to eye movements, following the

awakening from REM and NONREM sleep. The latter results strongly suggest that differential innervation of the oculomotor system was not the cause of the differences in perception observed by Berger and Scott, and also Berger and Walker, but rather these perceptual differences were caused by different arousal levels, undetected by the electrophysiological recordings.

The function or functions of the 90 min ultradian biorhythm can only be a matter of speculation at this stage. It may be that the periodic potentiation of the organism is only a by-product of another periodic event, or the alternation may serve an as yet unknown function in itself. In this context it is interesting to note Dement's (1973) analogy of the REM stage to meal time. According to Dement, the REM stage can be compared to a meal time, during which the human ingests large amounts of a variety of necessary dietary constituents and fluids, leaving him long intervals between meals in which to engage in other activities. In the same manner, he postulated, the REM sleep may be the most efficient way to "do something." "Just what is something," he continued, "we do not know." Perhaps this analogy can be extended to the broader 90 min rhythm.

Kripke recently noted that: "waking ultradian rhythms do appear to be related to appetitive functions ... it presently appears that eating, activity, fantasying, hormonal pulses, genital expressions, etc., may all be tied to the same oscillator, as if an ultradian oscillator modulates a polymorphous appetency similar to that hypothesized by Freud." (1973, 321). He continued to speculate that perhaps the

ultradian oscillatory systems are those by which certain appetencies are discharged before building to dangerous levels.

Besides subserving specific roles, the fact that periodic oscillations of activity and non-activity were found to operate on a neuronal level (Scheibel and Scheibel, 1965), and even in the primitive nervous system of the sea hare, the Aplysia Californica (Strumwasser, 1965), may indicate that oscillation between periods of activity and non-activity is an essential property of the functioning nervous system. However, much more information is needed in order to reach any conclusion with respect to the functions of the 90 min biorhythm, and whether it has the same functions as the REM-NONREM cycle

CONCLUSIONS

The results of the three experiments conducted in the present dissertation may lead to the following conclusions: 1) The REM-NONREM cycle and the waking ultradian rhythm in the perception of the SAE are continuous across the transition from sleep to wakefulness. 2) The range of the βM is a sensitive detector of the cortical states associated with wakefulness periods subsequent to awakenings from REM and NONREM sleep. 3) The range of the βM is also a sensitive detector of the phase of the waking ultradian biorhythm. There is evidence that the βM and the SAE rhythms were in phase across 8-hour experimental periods. 4) Both the REM-NONREM cycle and the waking ultradian rhythms are fragments of the same ultradian biorhythm operating across both sleep and wakefulness.

Appendix A

Raw Data and Analysis of Variance Summary Tables for Experiment 1

Table A-1

Spiral After-Effect Durations for the Four Awakening Conditions for the Two Groups of Subjects (in seconds).

Group 1

	Subject 1				Subject 2			
Trial	BR4*	MR3	BNR1	MNR2	BR3	MR4	BNR2	MNR1
1	3.85	5.00	9.25	7.30	13.00	6.95	10.70	14.15
2	3.45	6.20	8.60	8.15	9.30	4.95	10.20	12.00
3	3.25	4.65	8.70	5.65	8.90	6.35	10.25	9.65
4	3.55	4.00	7.55	6.75	6.75	5.70	8.95	7.40
5	4.05	3.55	7.35	5.10	9.70	4.25	8.55	8.85
6	3.35	4.30	6.90	5.55	7.15	3.50	8.75	11.30
7	2.70	4.15	7.60	4.20	6.75	3.70	6.80	8.10
8	2.15	4.55	6.10	4.85	8.20	4.50	8.45	9.10
9	3.05	3.50	6.10	5.60	7.15	5.65	6.15	8.30
10	2.15	4.20	6.65	5.45	7.70	5.40	8.15	8.50
11	2.45	3.50	7.30	7.15	6.10	5.90	9.00	7.60
12	2.25	5.05	7.65	6.70	6.60	4.10	7.70	9.10
13	2.45	3.55	7.70	6.05	6.90	5.65	9.05	8.40
14	3.10	4.00	5.75	6.75	8.05	5.75	7.90	7.35
15	2.05	4.65	5.65	5.15	6.90	6.55	7.80	7.15
16	2.55	3.45	5.05	5.90	6.20	5.00	6.75	10.80
17	2.50	4.10	6.70	3.80	5.80	6.15	8.30	10.45
18	2.25	3.40	7.10	7.40	8.50	4.85	8.05	8.95
19	2.00	3.90	7.00	6.80	7.80	4.60	8.35	9.65
20	2.05	4.20	6.65	6.30	7.10	4.35	8.45	11.75
21	1.65	4.50	6.30	7.40	9.05	5.15	8.75	11.20
22	1.90	3.80	5.70	6.65	7.95	3.70	6.80	10.75
23	2.05	3.90	6.60	8.05	7.65	3.30	9.05	9.60
24	1.85	4.20	5.65	5.65	8.90	4.00	10.85	10.60
25	1.60	4.90	6.70	6.20	8.85	5.20	9.65	8.70
26	2.35	4.00	6.15	5.10	6.90	5.35	11.00	9.50
27	2.65	4.75	7.00	7.35	5.95	6.10	9.35	10.00
28	2.20	4.90	5.45	6.00	7.35	6.95	8.50	8.70
29	1.55	5.05	6.25	6.60	5.65	6.90	7.50	12.35
30	2.35	3.90	7.70	6.70	7.10	4.70	10.05	11.20
31	2.40	4.25	7.15	7.40	7.60	5.90	9.35	10.35
32	1.90	3.55	5.25	8.25	7.25	4.15	9.75	10.60
33	2.35	4.85	6.15	7.35	7.30	4.55	10.65	10.80
34	3.20	4.85	6.30	5.35	6.05	5.65	8.80	9.90
35	3.25	3.90	7.60	7.30	6.30	5.30	8.45	10.35
36	3.65	5.50	7.00	9.40	6.90	4.35	8.20	10.10

* No. of experimental night.

Table A-1 (Continued)

	Subject 3				Subject 4			
Trial	BR2	MR1	BNR3	MNR4	BR1	MR2	BNR4	MNR3
1	9.65	10.10	7.80	6.10	4.55	4.65	3.20	4.35
2	9.65	9.90	8.95	7.20	4.05	5.05	4.10	3.85
3	8.80	7.35	9.80	5.90	4.40	3.80	4.40	3.10
4	9.00	10.80	8.40	4.90	3.90	6.00	3.95	4.20
5	7.55	8.70	6.70	6.40	4.25	3.95	4.55	3.75
6	6.70	11.95	7.15	7.65	4.35	3.85	4.05	3.95
7	8.80	8.20	10.65	4.95	4.50	4.60	4.65	3.90
8	6.50	9.55	8.25	4.30	5.45	5.20	4.95	3.40
9	6.70	5.85	6.40	5.15	4.20	5.05	3.75	4.20
10	7.75	9.00	5.90	5.55	3.85	5.40	4.05	3.65
11	5.15	8.60	9.05	7.25	3.55	4.75	3.40	4.00
12	4.30	6.75	7.50	7.85	4.25	4.70	4.35	3.75
13	7.75	6.90	9.30	4.55	4.55	4.10	4.30	4.15
14	5.15	9.00	9.00	6.45	4.60	5.05	3.85	3.85
15	3.60	5.20	8.55	7.50	4.75	4.10	4.45	4.25
16	6.90	6.20	6.75	4.35	4.55	3.90	4.00	4.10
17	5.30	7.15	8.50	5.55	4.60	3.75	4.15	4.40
18	6.10	8.60	7.15	5.05	3.80	4.00	4.05	3.80
19	5.65	9.20	6.00	4.50	5.05	4.85	3.10	3.45
20	4.20	6.45	6.60	4.65	4.10	4.20	4.20	3.40
21	5.05	6.40	6.00	3.45	4.10	4.10	4.60	3.90
22	6.70	5.80	8.25	4.60	4.00	3.70	4.00	3.40
23	7.20	8.35	8.90	6.00	4.30	3.90	4.45	3.40
24	6.65	7.45	8.60	4.65	3.70	2.85	5.45	4.05
25	7.90	9.45	7.55		4.50	3.60	5.35	4.10
26	7.60	7.45	8.70		4.65	3.50	5.35	3.50
27	6.40	5.60	7.60		4.15	3.95	4.90	3.15
28	5.30	6.45	8.25		5.75	3.15	3.80	3.60
29	5.10	5.70	5.80		3.90	4.40	4.20	4.70
30	5.75	7.25	5.25		3.70	3.35	4.00	4.70
31	5.20	8.15	3.95		4.95	4.50	5.45	4.15
32	6.10	9.35	8.05		4.25	3.80	4.05	4.40
33	6.90	6.65	6.90		4.40	3.60	3.50	3.95
34	5.95	6.60	6.40		3.65	3.50	3.40	4.50
35	6.10	7.30	6.25		3.75	4.05	3.70	3.70
36	6.50	8.05	6.65		4.25	2.75	3.55	3.85

Table A-1 (Continued)

Group 2

	Subject 1				Subject 2			
Trial	BR3	MR1	BNR4	MNR2	BR1	MR4	BNR2	MNR3
1	21.70	14.80	12.40	13.25	2.20	2.00	1.40	2.15
2	11.60	19.60	11.35	13.90	2.30	1.90	1.20	2.15
3	26.10	26.90	9.65	12.00	2.10	1.50	1.30	1.80
4	19.45	23.70	12.55	11.60	1.90	2.00	1.20	2.00
5	21.15	22.90	14.50	13.60	1.60	1.80	1.70	1.75
6	10.70	16.40	13.70	11.45	1.80	2.00	1.30	1.50
7	24.15	14.50	17.35	11.30	1.60	1.70	1.20	1.80
8	10.70	26.80	11.45	9.00	1.60	1.60	1.40	1.70
9	13.40	9.70	16.35	8.20	1.80	2.20	1.40	1.70
10	12.35	15.20	13.35	11.90	1.60	1.50	1.10	1.50
11	13.40	8.00	11.00	9.90	1.50	2.40	1.40	1.50
12	13.40	12.40	14.00	14.25	1.70	2.20	1.30	1.40
13	15.70	12.50	15.00	9.80	2.20	1.70	1.20	1.30
14	10.40	14.20	11.70	11.10	1.80	1.90	1.50	1.50
15	16.75	11.40	11.35	8.45	1.80	1.40	1.30	1.50
16	18.85	15.30	11.35	12.20	1.50	1.40	1.10	2.20
17	11.45	10.70	13.95	13.90	1.30	1.40	1.50	1.40
18	16.30	9.50	14.55	11.35	1.50	1.50	1.50	1.40
19	17.00	8.30	9.70	10.85	1.50	1.20	1.60	1.50
20	11.10	8.70	17.85	15.60	1.40	1.60	1.80	1.50
21	11.90	12.40	20.25	11.50	1.10	1.70	1.50	1.50
22	11.95	7.90	18.40	12.30	1.30	1.50	1.60	1.70
23	13.75	14.00	8.85	11.75	1.70	1.40	1.70	1.90
24	16.45	12.40	14.55	11.95	1.90	1.60	1.60	1.40
25	17.60	7.80	23.65	13.05	1.90	1.60	1.30	1.40
26	11.70	9.60	21.60	16.70	1.60	2.20	1.30	1.30
27	19.35	8.10	21.30	13.40	2.20	1.50	1.50	1.60
28	12.25	8.10	17.80	10.45	1.90	1.80	1.50	1.20
29	10.25	13.30	23.40	8.70	2.00	1.80	1.40	1.40
30	14.45	10.30	18.90	8.20	2.30	2.20	1.50	1.60
31	13.20	6.30	17.40	6.50	2.40	2.00	1.50	1.50
32	15.60	12.30	23.55	4.75	1.80	2.20	1.50	1.30
33	18.30	8.00	17.30	10.25	1.70	1.90	1.10	1.30
34	17.95	10.10	17.00	14.60	1.90	1.80	1.50	1.30
35	16.50	7.40	13.40	9.00	2.00	1.40	1.60	1.10
36	12.20	11.30	15.15	10.00	1.70	1.50	1.60	1.20

Table A-1 (Continued)

	Subject 3				Subject 4			
Trial	BR4	MR2	BNR3	MNR1	BR2	MR3	BNR1	MNR4
1	1.20	2.25	1.90	6.65	6.10	7.40	11.40	7.70
2	1.00	2.00	1.50	4.90	8.65	9.55	10.30	8.00
3	1.00	1.90	1.60	4.70	6.35	8.05	11.20	5.60
4	0.90	1.40	1.50	4.45	5.75	6.90	10.70	5.60
5	1.20	1.25	1.70	4.50	7.55	6.20	10.80	5.80
6	0.90	1.55	1.50	4.70	8.90	7.40	11.60	5.50
7	1.20	1.40	1.30	4.35	6.75	4.20	7.70	5.40
8	1.10	1.30	1.50	4.05	6.20	6.80	12.70	4.60
9	1.10	1.25	1.30	4.10	6.90	6.50	9.90	4.50
10	1.10	1.45	1.60	4.70	7.30	5.70	10.40	4.20
11	1.40	1.40	1.60	4.30	5.35	5.70	10.20	4.30
12	1.10	1.30	1.30	4.30	7.40	4.20	10.80	3.00
13	1.20	1.35	1.10	3.20	8.30	2.10	11.00	3.60
14	1.00	1.25	1.30	3.80	7.35	6.50	9.70	3.70
15	0.90	1.55	1.20	3.80	7.10	6.70	10.00	5.20
16	0.80	1.60	1.50	4.25	8.00	4.50	10.70	4.70
17	1.00	1.50	1.20	3.60	6.90	5.50	9.10	4.70
18	1.00	1.30	1.20	3.45	5.95	6.60	11.10	5.90
19	1.05	1.60	1.20	3.35	7.20	1.40	12.10	4.60
20	0.90	1.30	1.40	2.95	7.50	5.60	7.50	4.10
21	1.00	1.55	1.80	3.90	6.95	5.60	9.30	5.60
22	0.90	1.45	1.50	3.05	8.15	9.10	8.90	4.20
23	0.90	1.50	1.80	3.70	7.20	7.40	6.90	3.60
24	0.95	1.15	1.20	3.20	5.60	7.30	9.10	4.50
25	0.90	2.00	1.10	3.45	5.35	4.40	7.90	6.10
26	0.80	2.40	1.50	3.05	5.55	3.30	8.20	2.80
27	0.95	2.15	1.90	3.65	5.65	3.00	6.60	3.30
28	0.95	1.75	1.60	2.30	11.35	1.80	6.90	3.20
29	1.00	1.80	1.30	2.20	8.30	5.30	6.80	4.50
30	1.00	2.00	1.60	2.45	6.75	5.20	6.10	6.20
31	0.80	2.35	1.50	2.55	8.85	5.20	5.60	5.10
32	0.95	2.30	1.30	2.25	5.40	6.80	6.50	4.90
33	1.00	2.30	1.40	2.25	8.00	4.30	5.00	3.10
34	1.05	1.95	1.00	2.25	6.40	5.00	4.40	4.50
35	0.90	2.15	1.20	2.75	5.70	5.05	4.30	7.90
36	1.00	2.10	1.40	2.50	5.70	5.00	4.50	5.00

Table A-2

Analysis of Variance for 5 Degree Polynomial
of MNR Condition of Group 1

Source	df	MS	F
Linear	1	1.75881	8.90****
Quadratic	1	0.79623	4.03
Cubic	1	0.45961	2.32
Quartic	1	0.04676	-
Quintic	1	1.83211	9.27****
Error	29	0.19740	

**** $p < 0.005$

Table A-3

Analysis of Variance for 5 Degree Polynomial
of MNR Condition of Group 1

Source	df	MS	F
Linear	1	0.59504	2.78
Quadratic	1	0.16503	-
Cubic	1	1.03067	4.81*
Quartic	1	0.02036	-
Quintic	1	0.00881	-
Error	29	0.21385	

* $p < 0.05$

Table A-4

Analysis of Variance for 5 Degree Polynomial
of BR Condition of Group 1

Source	df	MS	F
Linear	1	1.72348	12.43****
Quadratic	1	1.51017	10.89****
Cubic	1	1.45888	10.46****
Quartic	1	0.02035	-
Quintic	1	0.86211	6.22**
Error	29	0.13857	

**** $p < 0.005$ ** $p < 0.025$

Table A-5

Analysis of Variance for 5 Degree Polynomial
of MR Condition of Group 1

Source	df	MS	F
Linear	1	1.32281	7.30**
Quadratic	1	1.07761	5.94**
Cubic	1	0.11823	-
Quartic	1	0.00524	-
Quintic	1	0.47834	2.64
Error	29	0.18114	

** $p < 0.025$

Table A-6

Analysis of Variance for 5 Degree Polynomial of MNR Condition of Group 2

Source	df	MS	F
Linear	1	5.23212	56.23*****
Quadratic	1	0.18617	1.98
Cubic	1	0.63337	6.79**
Quartic	1	1.38689	14.87*****
Quintic	1	0.17038	1.82
Error	29	0.09321	

***** $p < 0.001$ ** $p < 0.025$

Table A-7

Analysis of Variance for 5 Degree Polynomial of ENR Condition of Group 2

Source	df	MS	F
Linear	1	0.00298	-
Quadratic	1	0.57216	5.72*
Cubic	1	0.97464	9.74****
Quartic	1	0.11588	1.15
Quintic	1	0.87654	8.76***
Error	29	0.10172	

* $p < 0.05$ *** $p < 0.01$ **** $p < 0.005$

Table A-8

Analysis of Variance for 5 Degree Polynomial of MR Condition of Group 2

Source	df	MS	F
Linear	1	0.85691	7.08**
Quadratic	1	2.94888	24.29*****
Cubic	1	0.81306	6.71**
Quartic	1	0.29360	2.52
Quintic	1	0.17756	1.41
Error	29	0.12103	

** $p < 0.025$ ***** $p < 0.001$

Table A-9

Analysis of Variance for 5 Degree Polynomial of BR Condition of Group 2

Source	df	MS	F
Linear	1	0.64807	3.71
Quadratic	1	1.04551	5.98**
Cubic	1	0.08764	-
Quartic	1	0.72284	4.15
Quintic	1	0.69303	3.97
Error	29	0.17457	

** $p < 0.025$

Table A-10

Analysis of Variance for 5 Degree Polynomial
of Pooled REM condition of Group 1

Source	df	MS	F
Linear	1	1.50665	25*****
Quadratic	1	1.27568	21.16*****
Cubic	1	0.59921	9.83****
Quartic	1	0.00147	-
Quintic	1	0.01363	-
Error	29	0.06421	

**** $p < 0.005$ ***** $p < 0.001$

Table A-11

Analysis of Variance for 5 Degree Polynomial
of Pooled NONREM Condition of Group 1

Source	df	MS	F
Linear	1	0.07388	-
Quadratic	1	0.41655	5.48*
Cubic	1	0.72027	9.41****
Quartic	1	0.00158	-
Quintic	1	0.51864	6.78**
Error	29	0.07647	

* $p < 0.05$ **** $p < 0.005$ ** $p < 0.025$

Table A-12

Analysis of Variance for 5 Degree Polynomial
of Pooled REM Condition of Group 2

Source	df	MS	F
Linear	1	0.74871	32.41*****
Quadratic	1	1.85800	80*****
Cubic	1	0.35735	15.20*****
Quartic	1	0.47952	20.43*****
Quintic	1	0.38499	16.78*****
Error	29	0.02310	

***** $p < 0.001$

Table A-13

Analysis of Variance for 5 Degree Polynomial
of Pooled NONREM Condtion of Group 2

Source	df	MS	F
Linear	1	1.36198	28.76*****
Quadratic	1	0.02534	-
Cubic	1	0.78449	16.56*****
Quartic	1	0.17174	3.62
Quintic	1	0.44914	9.49****
Error	29	0.04735	

**** $p < 0.005$ ***** $p < 0.001$

Table A-14

Mean Spiral After-Effect Durations and Standard Deviations (in sec.) of the 11 Practice Trials Given Prior to Sleep

	Experimental Session	Group 1 Mean	Group 1 Sd	Group 2 Mean	Group 2 Sd
Subject 1	1	9.03	2.31	9.74	2.11
	2	6.12	0.90	13.26	2.45
	3	7.32	1.65	13.53	2.31
	4	5.53	1.26	16.36	4.27
Subject 2	1	12.46	1.51	2.44	0.75
	2	8.32	1.32	1.44	0.09
	3	11.49	0.99	1.51	0.15
	4	7.25	1.01	1.65	0.27
Subject 3	1	11.53	1.46	4.82	1.33
	2	9.45	1.15	2.00	0.32
	3	9.75	1.59	1.65	o.14
	4	7.52	0.95	1.33	0.21
Subject 4	1	5.66	1.29	11.93	1.88
	2	5.43	0.76	8.07	1.66
	3	4.26	0.35	6.97	1.54
	4	3.86	0.28	5.67	0.76

Appendix B

Raw Data and Analysis of Variance Summary Tables for Experiment 2

Table B-1

Beta Movement Upper Limits for the Waking (W), REM (R), and NONREM (NR), Conditions
Group 1

		W			R			NR		
Ss		1	2	3	1	2	3	1	2	3
1	Day 1	1.68	1.62	1.62	1.61	1.63	1.64	1.64	1.65	1.65
	Day 2	1.63	1.61	1.65	1.65	1.66	1.65	1.57	1.61	1.60
2	Day 1	1.72	1.63	1.64	1.68	1.67	1.67	1.65	1.64	1.63
	Day 2	1.78	1.84	1.92	2.10	2.02	2.00	2.06	2.07	2.10
3	Day 1	1.82	1.87	1.94	2.12	1.99	1.97	1.96	1.96	1.87
	Day 2	1.80	1.90	1.82	1.90	1.93	1.89	1.91	1.87	1.82
4	Day 1	2.06	1.95	1.88	1.99	2.03	2.08	1.87	1.91	1.82
	Day 2	1.87	1.78	1.71	1.82	1.77	1.82	1.87	1.91	1.86
5	Day 1	1.95	2.03	1.70	1.92	1.75	1.71	1.70	1.62	1.62
	Day 2	1.63	1.63	1.61	1.76	1.51	1.50	1.53	1.60	1.52
					Group 2					
1	Day 1	1.88	1.84	1.88	1.92	1.92	1.96	1.88	1.96	1.91
	Day 2	1.93	2.02	1.96	2.14	2.12	2.10	1.99	2.00	1.99
2	Day 1	1.67	1.70	1.82	1.73	1.69	1.63	1.85	1.64	1.67
	Day 2	1.93	1.85	1.85	1.71	1.74	1.70	1.80	1.74	1.68
3	Day 1	1.75	1.69	1.69	1.72	1.82	1.85	1.59	1.60	1.53
	Day 2	1.61	2.06	1.97	1.82	1.80	1.77	1.97	1.96	1.95
4	Day 1	1.86	1.75	1.73	1.93	1.99	1.99	1.95	1.86	1.82
	Day 2	1.96	1.86	1.84	1.94	1.97	1.95	1.88	1.87	1.86
5	Day 1	1.77	1.74	1.65	1.78	1.75	1.82	1.86	1.87	1.71
	Day 2	1.71	1.80	1.81	1.69	1.70	1.68	1.74	1.80	1.81

Table B-2

Beta Movement Lower Limits for the Waking (W), REM (R) and NONREM (NR) Conditions

Group 1

		W			R			NR		
Ss		1	2	3	1	2	3	1	2	3
1	Day 1	1.61	1.54	1.55	1.53	1.53	1.54	1.55	1.55	1.54
	Day 2	1.56	1.53	1.56	1.55	1.54	1.54	1.50	1.54	1.53
2	Day 1	1.61	1.53	1.56	1.52	1.51	1.50	1.55	1.51	1.51
	Day 2	1.64	1.75	1.81	1.95	1.89	1.91	1.95	1.96	2.00
3	Day 1	1.49	1.57	1.65	1.60	1.53	1.51	1.54	1.59	1.49
	Day 2	1.58	1.66	1.53	1.52	1.55	1.55	1.68	1.64	1.61
4	Day 1	1.84	1.81	1.76	1.77	1.80	1.84	1.77	1.81	1.72
	Day 2	1.74	1.66	1.56	1.62	1.56	1.61	1.74	1.76	1.75
5	Day 1	1.69	1.77	1.60	1.79	1.66	1.63	1.63	1.57	1.57
	Day 2	1.47	1.51	1.50	1.65	1.40	1.39	1.46	1.52	1.45

Group 2

1	Day 1	1.77	1.73	1.75	1.74	1.76	1.81	1.81	1.89	1.84
	Day 2	1.77	1.85	1.82	1.93	1.92	1.92	1.89	1.91	1.90
2	Day 1	1.49	1.53	1.54	1.37	1.46	1.50	1.66	1.40	1.48
	Day 2	1.75	1.65	1.65	1.51	1.54	1.49	1.59	1.58	1.53
3	Day 1	1.55	1.47	1.48	1.52	1.61	1.66	1.42	1.43	1.35
	Day 2	1.33	1.92	1.85	1.55	1.52	1.46	1.87	1.88	1.85
4	Day 1	1.59	1.61	1.61	1.79	1.86	1.80	1.87	1.78	1.74
	Day 2	1.74	1.68	1.66	1.74	1.79	1.79	1.78	1.77	1.77
5	Day 1	1.63	1.56	1.49	1.45	1.44	1.50	1.75	1.77	1.60
	Day 2	1.53	1.62	1.65	1.43	1.42	1.40	1.62	1.70	1.70

Table B-3

Beta Movement Medians for the Waking (W), REM (R), and NONREM (NR) Conditions

Group 1

		W			R			NR		
Ss		1	2	3	1	2	3	1	2	3
1	Day 1	1.65	1.57	1.57	1.57	1.58	1.60	1.60	1.62	1.61
	Day 2	1.60	1.60	1.62	1.58	1.60	1.60	1.55	1.57	1.56
2	Day 1	1.66	1.57	1.60	1.61	1.61	1.58	1.61	1.60	1.58
	Day 2	1.70	1.82	1.83	2.02	1.96	1.95	2.03	2.02	2.10
3	Day 1	1.73	1.70	1.81	1.82	1.76	1.71	1.75	1.79	1.65
	Day 2	1.67	1.77	1.66	1.71	1.73	1.70	1.76	1.77	1.75
4	Day 1	2.06	1.85	1.82	1.85	1.92	1.96	1.82	1.80	1.77
	Day 2	1.85	1.75	1.65	1.70	1.68	1.76	1.80	1.85	1.80
5	Day 1	1.78	1.91	1.77	1.92	1.68	1.65	1.61	1.61	1.60
	Day 2	1.55	1.65	1.57	1.62	1.43	1.47	1.53	1.57	1.50

Group 2

1	Day 1	1.83	1.80	1.81	1.83	1.83	1.88	1.85	1.93	1.87
	Day 2	1.85	1.92	1.91	2.02	2.00	2.02	1.95	1.95	1.95
2	Day 1	1.62	1.62	1.71	1.58	1.62	1.56	1.80	1.55	1.57
	Day 2	1.85	1.82	1.73	1.62	1.65	1.60	1.75	1.67	1.61
3	Day 1	1.71	1.60	1.61	1.61	1.70	1.71	1.53	1.42	1.42
	Day 2	1.48	2.01	1.90	1.71	1.67	1.63	1.96	1.92	1.90
4	Day 1	1.72	1.66	1.58	1.63	1.62	1.65	1.86	1.82	1.67
	Day 2	1.70	1.66	1.58	1.58	1.56	1.53	1.71	1.75	1.75
5	Day 1	1.82	1.80	1.73	1.82	1.88	1.87	1.83	1.83	1.82
	Day 2	1.72	1.68	1.67	1.88	1.90	1.87	1.82	1.82	1.78

Table B-4

Beta Movement Ranges for the Waking (W), REM (R), and NONREM (NR) Conditions

Group 1

	W			R			NR		
Ss	1	2	3	1	2	3	1	2	3
1 Day 1	.07	.08	.07	.07	.09	.09	.09	.10	.11
Day 2	.07	.08	.08	.10	.11	.11	.06	.07	.07
2 Day 1	.10	.10	.08	.15	.16	.16	.10	.12	.12
Day 2	.14	.09	.10	.15	.12	.09	.10	.11	.10
3 Day 1	.32	.30	.28	.51	.45	.45	.42	.37	.37
Day 2	.21	.23	.28	.37	.38	.34	.23	.23	.21
4 Day 1	.22	.14	.12	.22	.23	.24	.10	.10	.10
Day 2	.12	.11	.15	.19	.20	.15	.13	.15	.10
5 Day 1	.26	.25	.10	.13	.09	.08	.07	.05	.04
Day 2	.15	.12	.11	.11	.10	.10	.07	.07	.07

Group 2

1 Day 1	.10	.10	.13	.18	.15	.15	.07	.07	.07
Day 2	.16	.17	.13	.20	.19	.18	.10	.09	.09
2 Day 1	.17	.16	.28	.35	.22	.13	.18	.23	.18
Day 2	.18	.20	.20	.20	.20	.20	.20	.15	.14
3 Day 1	.19	.21	.20	.20	.20	.18	.17	.17	.17
Day 2	.21	.18	.17	.19	.17	.16	.10	.10	.09
4 Day 1	.13	.17	.17	.33	.30	.32	.10	.10	.11
Day 2	.18	.17	.16	.25	.28	.28	.11	.10	.10
5 Day 1	.27	.13	.12	.13	.13	.22	.08	.08	.07
Day 2	.21	.18	.17	.19	.17	.16	.10	.10	.09

Table B-5

Analysis of Variance for Upper Limits of the Beta Movement

Source	df	MS	F
Groups (A)	1	.081	-
Days (D)	1	.040	-
Tests (T)	2	.020	1.220
Blocks (B)	2	.012	2.629
S(A)	8	1.759	
AD	1	.093	-
AT	2	.002	-
DT	2	.021	1.563
AB	2	.004	-
DB	2	.006	3.771*
TB	4	.002	-
SD(A)	8	.109	
ST(A)	16	.016	
SB(A)	16	.004	
ADT	2	.021	1.578
ADB	2	.001	1.080
ATB	4	.005	1.148
DBT	4	.026	1.566
SDT(A)	16	.013	
SDB(A)	16	.001	
STB(A)	32	.004	
ADBT	4	.001	-
SDBT(A)	32	.004	

* $p < 0.05$

Table B-6

Analysis of Variance for Lower Limits of the Beta Movement

Source	df	MS	F
Groups (A)	1	.048	-
Days (D)	1	.090	-
Tests (T)	2	.038	1.993
Blocks (B)	2	.004	1.208
S(A)	8	.209	
AD	1	.041	-
AT	2	.017	-
DT	2	.028	1.608
AB	2	.004	1.329
DB	2	.004	1.618
TB	4	.004	1.137
SD(A)	8	.105	
ST(A)	16	.019	
SB(A)	16	.003	
ADT	2	.019	1.097
ADB	2	.002	-
ATB	4	.004	1.283
DBT	4	.009	1.656
SDT(A)	16	.018	
SDB(A)	16	.002	
STB(A)	32	.003	
ADBT	4	.003	-
SDBT(A)	32	.005	

Table B-7

Analysis of Variance for Medians of the Beta Movement

Source	df	MS	F
Groups (A)	1	.064	-
Days (D)	1	.045	-
Tests (T)	2	.003	-
Blocks (B)	2	.012	4.029*
S(A)	8	.176	
AD	1	.041	-
AT	2	.007	-
DT	2	.035	2.183
AB	2	.000	-
DB	2	.008	4.031*
TB	4	.001	-
SD(A)	8	.113	
ST(A)	16	.018	
SB(A)	16	.003	
ADT	2	.007	-
ADB	2	.000	-
ATB	4	.005	-
DBT	4	.007	1.888
SDT(A)	16	.016	
SDB(A)	16	.002	
STB(A)	32	.005	
ADBT	4	.001	-
SDBT(A)	32	.004	

* $p < 0.05$

Table B-8

Analysis of Variance for Ranges of the Beta Movement

Source	df	MS	F
Groups (A)	1	.004	-
Days (D)	1	.010	1.933
Tests (T)	2	.093	11.067***
Blocks (B)	2	.004	7.836**
S(A)	8	.096	
AD	1	.011	2.040
AT	2	.008	1.034
DT	2	.000	-
AB	2	.000	-
DB	2	.000	-
TB	4	.000	-
SD(A)	8	.005	
ST(A)	16	.008	
SB(A)	16	.000	
ADT	2	.000	-
ADB	2	.000	1.169
ATB	4	.000	-
DBT	4	.002	-
SDT(A)	16	.001	
SDB(A)	16	.003	
STB(A)	32	.001	
ADBT	4		3.00
SDBT(A)	32		

** $p < 0.01$ *** $p < 0.005$

Appendix C

Raw Data and F Ratios of Linear Trends for Experiment 3

Table C-1

Beta Movement Ranges Taken Every 20 minutes (in fps)

Group 1

Trial \ Ss	ST	JE	AA	AL	RI	EU	IV	HE
1	.165	.325	.120	.215	.240	.160	.120	.195
2	.150	.200	.150	.075	.255	.160	.105	.200
3	.215	.225	.100	.125	.200	.140	.100	.150
4	.120	.200	.210	.090	.175	.100	.110	.195
5	.140	.175	.125	.100	.150	.120	.100	.175
6	.185	.250	.160	.125	.190	.125	.100	.230
7	.090	.290	.115	.150	.180	.125	.070	.245
8	.085	.170	.125	.185	.200	.170	.100	.255
9	.055	.180	.165	.225	.190	.170	.110	.215
10	.125	.180	.140	.090	.175	.150	.090	.225
11	.115	.145	.085	.115	.170	.150	.110	.200
12	.120	.290	.115	.075	.170	.135	.125	.320
13	.175	.210	.140	.115	.190	.160	.065	.245
14	.215	.125	.085	.100	.195	.095	.115	.220
15	.155	.165	.085	.085	.170	.155	.090	.205
16	.150	.265	.090	.100	.160	.180	.100	.225
17	.130	.145	.085	.125	.165	.175	.105	.200
18	.165	.230	.165	.115	.180	.105	.110	.200
19	.190	.205	.075	.125	.175	.130	.075	.230
20	.150	.180	.065	.165	.170	.110	.075	.220
21	.160	.180	.090	.100	.165	.110	.085	.225
22	.205	.265	.100	.150	.155	.130	.100	.205
23	.215	.235	.100	.110	.175	.140	.115	.230
24	.210	.235	.060	.190	.170	.120	.100	.225

Table C-1 (Continued)

Group 2

Ss / Trial	PE	DA	BRU	BR	HO	PH
1	.215	.080	.275	.160	.110	.115
2	.160	.090	.215	.255	.135	.135
3	.135	.090	.225	.285	.135	.155
4	.130	.180	.175	.280	.170	.140
5	.110	.115	.200	.330	.190	.165
6	.130	.110	.160	.360	.150	.100
7	.135	.125	.175	.380	.140	.100
8	.100	.125	.180	.255	.160	.085
9	.100	.100	.200	.240	.150	.075
10	.115	.085	.200	.290	.150	.110
11	.130	.090	.175	.235	.140	.140
12	.130	.100	.235	.240	.140	.105
13	.135	.145	.255	.255	.220	.075
14	.115	.110	.210	.260	.230	.075
15	.110	.090	.200	.200	.190	.100
16	.125	.105	.200	.180	.150	.090
17	.115	.100	.255	.175	.130	.120
18	.090	.110	.250	.150	.120	.080
19	.090	.070	.210	.175	.140	.115
20	.100	.075	.185	.160	.080	.165
21	.110	.075	.250	.100	.080	.100
22	.115	.085	.215	.165	.150	.080
23	.100	.075	.205	.130	.195	.085
24	.080	.090	.205	—	.100	.085

Table C-2

Spiral After-Effect Durations Taken Every 20 minutes (in sec.)

Group 1

Trial	Ss	ST	JE	AA	AL	RI	EU	IV	HE
1		4.25	4.60	1.40	2.35	3.20	2.90	3.70	3.25
2		3.80	4.50	1.10	2.70	3.00	2.67	3.55	5.10
3		4.30	3.50	1.50	3.80	3.37	3.02	2.90	3.95
4		4.15	2.65	1.30	1.80	2.90	2.70	2.80	3.85
5		3.60	3.45	1.10	2.20	2.50	2.52	2.10	4.30
6		3.35	4.20	1.05	1.80	3.10	2.67	2.15	3.30
7		4.25	3.70	1.20	2.35	3.17	2.50	2.20	3.45
8		3.90	3.40	1.05	1.90	3.80	2.27	2.30	4.45
9		5.55	2.45	1.00	1.85	2.92	2.30	2.80	3.25
10		5.10	1.90	1.55	1.80	3.17	2.50	1.75	3.40
11		4.35	1.50	1.35	1.70	2.70	2.46	2.80	3.15
12		3.75	1.65	1.60	1.85	3.27	2.55	2.05	3.00
13		3.02	2.95	1.15	1.80	2.96	2.50	2.20	3.30
14		4.88	3.00	1.05	2.00	3.30	2.02	2.05	4.25
15		6.28	2.55	0.95	1.45	3.25	2.30	2.00	2.85
16		4.13	3.15	1.35	1.65	3.37	2.57	1.90	2.55
17		3.25	2.40	1.15	1.40	3.55	2.40	1.30	3.05
18		3.75	3.55	1.00	1.60	3.80	2.97	1.36	2.65
19		3.90	2.25	0.70	1.70	3.02	2.27	1.20	2.90
20		3.98	2.25	0.60	1.60	3.30	1.87	1.95	2.95
21		4.05	2.65	0.70	1.75	2.55	2.50	2.25	2.80
22		4.12	2.15	0.80	2.00	2.55	2.07	1.60	2.65
23		4.08	2.30	1.10	1.60	2.97	2.00	1.65	2.95
24		3.53	2.35	1.10	2.60	2.85	2.25	1.80	2.85

Table C-2 (Continued)

Group 2

Ss / Trial	PE	DA	BRU	BR	HO	PH
1	7.70	4.30	2.20	5.95	5.15	3.50
2	5.82	4.00	2.00	7.15	5.10	3.17
3	5.67	4.30	1.80	5.95	4.75	2.85
4	5.47	5.10	1.80	5.00	5.00	4.25
5	5.20	3.90	2.15	5.25	3.85	3.65
6	5.15	3.95	1.80	3.40	3.52	2.74
7	4.92	4.85	2.10	3.65	3.76	2.75
8	5.22	3.75	2.55	4.10	3.20	3.70
9	4.10	4.75	2.25	3.55	3.26	3.25
10	4.22	5.65	1.55	4.85	3.52	3.15
11	4.40	5.35	2.67	4.20	4.10	3.25
12	4.10	3.85	2.45	5.75	4.12	3.40
13	3.85	3.35	2.32	4.55	4.10	2.55
14	3.87	3.85	2.22	3.00	4.25	2.35
15	3.72	3.95	1.45	3.25	4.02	2.45
16	3.62	4.15	2.05	2.75	3.62	2.75
17	3.67	3.45	2.02	2.30	4.17	2.80
18	4.70	2.90	2.82	1.55	3.35	3.15
19	3.57	2.70	1.95	1.70	3.42	2.40
20	3.75	4.10	2.80	1.95	3.12	2.85
21	3.77	2.80	3.07	1.15	3.10	2.90
22	3.80	3.50	2.42	0.95	3.22	2.45
23	3.62	3.15	2.47	2.30	3.85	2.95
24	3.40	3.45	1.60	1.40	3.95	2.75

Table C-3

F Ratios and Significance Levels of the Linear Trends for the Beta-Movement (N = 24) and Spiral After-Effect (N = 96) Time series

Group 1

	SAE		BM	
Ss	F	p	F	p
ST	6.18	.025	3.87	n.s.
JE	81.19	.001	0.30	n.s.
AA	41.17	.001	11.59	.005
AL	32.75	.001	0.00	n.s.
RI	2.83	n.s.	11.94	.005
EU	28.66	.001	3.32	n.s.
IV	67.56	.001	0.88	n.s.
HE	58.76	.001	1.39	n.s.

Group 2

DA	59.23	.001	4.83	.05
BR	229.36	.001	20.45	.001
PH	52.77	.001	4.22	n.s.
PE	170.89	.001	24.40	.001
BRU	2.51	n.s.	0.18	n.s.
HO	22.35	.001	0.55	n.s.

REFERENCES

Agnew, H. W., and Webb, W. B. The influence of time course variables on REM sleep. Bull. Psychon. Soc., 1973, 2, 131-133.

Andersson, A.L. Adaptive regulation of visual after-effect duration and social emotional adjustment. Acta Psychol., 1969, 29, 1-34.

Aserinsky, E., and Kleitman, N. Regularly occuring periods of eye motility, and concomitants phenomena during sleep. Science, 1953, 118, 273-274.

Bender, M.B., and Teuber, H.L. Disturbances in visual perception following cerebral lesions. J. Psychol., 1949, 28, 223-233.

Berger, R.J., and Scott, T.D. Increased accuracy of binocular depth perception following REM sleep periods. Psychophysiol., 1971, 8, 763-768.

Berger, R.J. Oculomotor control: A possible function of REM sleep. Psychol. Rev., 1969, 76, 144-164.

Berger, R.J., and Walker, J.M. Oculomotor coordination following REM and NONREM sleep periods. J. Exp. Psychol., 1972, 94, 216-224.

Blackman, R.B., and Tukey, J.W. The measurement of power spectra. New York: Dover Publications, 1958.

Blake, M.J.F. Temperament and time of day. In W.P. Colquhoun (Ed.), Biological rhythms and human performance. London: Academic Press, 1971.

Brebbia, D.R., and Altshuler, K. Z. Stage related patterns and nightly trends of energy exchange during sleep. In

N. Kline, E. Laska (Eds.), Computer and electronic devices in psychiatry. New York: Grune & Stratton, 1968.

Broughton, R.J. Sleep disorders: Disorders of arousal? Science, 1968, 159, 1070-1078.

Cartwright, R.D., Monroe, L.J., and Palmer, C. Individual differences in response to REM deprivation. Arch. Gen. Psychiat., 1967, 16, 297-303.

Coccagna, G., Mantovani, M., Brignani, F., Manzini, A., and Lugaresi, E. Arterial pressure changes during spontaneous sleep in man. Electroenceph. Clin. Neurophysiol., 1971, 31, 227-280.

Dement, W. The effect of dream deprivation. Science, 1960, 131, 1705-1707.

Dement, W. Studies on the function of rapid eye movement (paradoxical) sleep in human subjects. In M. Jouvet (Ed.), Aspects anatomofonctionnels de la physiologie du sommeil. Paris: Centre National de la Recherche Scientifique, 1965.

Dement, W. Recent studies on the biological theory of dreaming. Discussion. Amer. J. Psychiat., 1966, 123, 126-142.

Dement, W. Commentary, In W.B. Webb (Ed.), Sleep: An active process. Glenview, Illinois: Scott, Foresman, 1973.

Dement, W., and Kleitman, N. Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. Electroenceph. Clin. Neurophysiol., 1957, 9, 673-690.

Dement, W., Rechtschaffen, A., and Gulevich, G. The nature of the narcoleptic sleep attack. Neurol., 1966, 16, 18-33.

Dement, W., Cohen, H., Ferguson, J., and Zarcone, V. A sleep researcher's odyssey: The function and clinical significance of REM sleep. In L. Madow, L.H. Snow (Eds.) The psychodynamic implication of the physiological studies on dreams. Springfield, Illinois: Charles C. Thomas, 1970.

Dement, W., Zarcone, V., Ferguson, J., Cohen, H., Pivik, T., and Barchas, J. Some parallel findings in schizophrenic patients and serotonin-depleted cats. In S. Sekar (Ed.), Schizophrenia: Current concepts and research. New York: Plenum Press, 1971.

Denisova, M.P., and Fingurin, N.L. Periodic phenomena in the sleep of children. Novoe. Refl. Fiziol. Nerv. Systemy, 1926, 2, 338. Cited by N. Kleitman, Sleep and Wakefulness. (2nd ed.) Chicago: University of Chicago Press, 1963.

Dewan, E.M. The programing (P) hypothesis for rems. Bedford, Mass.: Air Force Cambridge Research Laboratories Report ARCRL-69-0298, 1969.

Duffy, E. Activation. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of psychophysiology. New York: Holt, Rinehart and Winston, 1972.

Ephron, H.S., and Carrington, P. Rapid eye movement sleep and cortical homeostasis. Psychol. Rev., 1966, 73, 500-526.

Feldman, S.M., and Waller, H.J. Dissociation of electrocortical activation and behavioral arousal. Nature, 1962, 196, 1320-1322.

Feltin, M., and Broughton, R.J. Differential effects of arousal from slow wave sleep and REM sleep. Psychophysiol., 1968, 5, 231.

Fiss, H., Klein, G.S., and Bokert, E. Waking fantasis following interruptions of two types of sleep. Arch. Gen. Psychiat., 1966, 19, 543-551.

Frazier, T.W., West, V., Every, M.G., and Parker, F.J. Use of spectral analysis in the study of human behavioral and physiological response measures. Research Report, U.S. Army Medical Research and Development Command, June, 1971.

Friedman, S. Oral activity cycles in mild chronic schzophrenia. Amer. J. Psychiat., 1968, 125, 743-751.

Friedman, S. On the presence of a variant form of instinctual regression: Oral drive cycles in obesity-bulimia. Psychoana. Quart., 1972, 41, 364-383.

Friedman, S., and Fisher, C. On the presence of rhythmic, diurnal, instinctual, drive cycle in man. J. Amer. Psychoana. Assoc., 1967, 15, 317-343.

Foret, J. Patterns of diurnal and nocturnal sleep stages. In H.M. Chase, W.C. Stern and P.L. Walter (Eds.), Sleep research, 1973, 2, 185 (abstract).

Globus, G.G., Drury, R.I., Phoebus, E.C., and Boyd, R. Ultradian rhythms in human performance. Percept. Motor Skills, 1971, 33, 1171-1174.

Globus, G.G., Phoebus, E.C., Humphries, J., Boyd, R., and Sharp, R. Ultradian rhythms in human telemetered motor activity. Aerospace Med., 1973, 44, 882-887.

Halberg, F. Physiologic considerations underlying rhythmometry, with special reference to emotional illness. In J. Ajuriaguerra (Ed.), Cycles biologiques et psychiatrie, Geneve, 1967.

Jenkins, G.M., and Watts, D.G. Spectral analysis and its applications, San Francisco: Holden Day, 1968.

Kales, A., and Tan, T.L. Sleep alterations associated with medical illness. In A. Kales (Ed.), Sleep physiology and pathology, Philadelphia: Lippincott, 1969.

Karacan, I., and Goodenough, D. REM deprivation in relation to erection cycle during sleep in adults. Paper presented at the Association for the Psychophysiological Study of Sleep, Gainesville, Florida, March 1966.

Karacan, I., Hursch, C.J., Williams, R.L., and Thornby, J.I. Some characteristics of nocturnal penile tumescence in young adults. Arch. Gen. Psychiat., 1972, 26, 351-356.

Kendall, M.G. Rank correlation methods. London: Griffin, 1948.

Kleitman, N. The nature of dreaming. In G.E.W. Wolstenholm, and M. O'Connor (Ed.), Ciba foundation symposium on the nature of sleep. London: J. & A. Churchill, 1961.

Kleitman, N. Sleep and wakefulness. (2nd ed.) Chicago: University of Chicago Press, 1963.

Kleitman, N. Basic rest-activity cycle in relation to sleep and wakefulness. In A. Kales (Ed.), Sleep: physiology and pathology. Philadelphia: Lippincott, 1969.

Kleitman, N. Implications of the rest-activity cycle: Implications for the organization of activities. In E. Hartman (Ed.), Sleep and daydreaming. Boston: Little, Brown, 1970.

Kleitman, N. The basic rest-activity cycle in sleep and wakefulness. In J. Jovanovic (Ed.), The nature of sleep. Gustav Fischer, Verlag, 1973.

Kragh, U. The actual-genetic model of perception-personality. Lund: Gleerup, 1955.

Kripke, D.F. An ultradian biologic rhythm associated with perceptual deprivation and REM sleep. Psychosom. Med., 1972, 34, 221-234.

Kripke, D.F. Ultradian rhythms in sleep and wakefulness. In E.D. Weitzman (Ed.), Advances in sleep research vol. 1. Flushing, N.Y.: Spectrum Publications, 1974.

Kripke, D.F., Halberg, F., Crowly, T.J., and Pegram, G.V. Ultradian rhythms in Rhesus monkeys. Psychophysiol., 1970, 7, 307-308.

Kripke, D.F., and Sonnenshein, D. A 90 minute daydream cycle. In H.M. Chase, W.C. Stern, and P.L. Walter (Eds.), Sleep research, 1973, 2, 187 (abstract).

Lane, W.P., and Horne, E.P. Stimulus intensity and position effects on apparent movement. J. Gen. Psychol., 1964, 71, 87-92.

Lavie, P. Differential effects of REM and NONREM awakenings on the spiral after effect. Physiol. Psychol., in press.

Lavie, P., and Giora, Z. Spiral after-effect durations following awakening from REM sleep and NONREM sleep. Percep. & Psychophy., 1973, 1, 19-20.

Lavie, P., Lord, J.W., and Frank, A.B. Basic rest-activity cycle in the perception of the spiral after-effect; A sensitive detector of a basic biological rhythm. Behav. Biol., in press.

Lavie, P., Levy, C.M., and Coolidge, L.F. Ultradian rhythms in the perception of the spiral after-effect. Paper submitted to press.

Magnussen, G. Studies on the respiration during sleep. A contribution to the physiology of the sleep function. London: H.K. Lewis, 1944.

Mandell, A.J., Brill, P.L., Mandell, M.P., Rodnick, J., Rubin, R.T., Sheff, R., and Chaffey, B. Urinary excretion of 3-methoxy-4-hydroxy-mandelic acid during dreaming sleep in man. Life Sci., 1966, 5, 169-173.

Myers , J.L. Fundamentals of experimental design. Boston: Allyn and Bacon, 1969.

Moses, J., Lubin, A., Naitoh, P., and Johnson, L.C. Reliability of sleep measures. Psychophysiol., 1972, 9, 78-82.

Ohlmeyer, P., Brilmayer, H., and Huellstrung, H. Periodisch vorgaenge in schalf. Pflu. Arch. Ges. Physiol., 1944, 248, 599.

Orr, C.W., Hoffman, H.J., and Hegge, F.W. Sleep loss, sustained performance, and the Basic Rest-Activity Cycle. In H.M. Chase, W.C. Stern, and P.L. Walter (Eds.), Sleep research, 1973, 2, 190 (abstract).

Oswald, J., Merrington, J., and Lewis, H. Cyclic "on demand" oral intake by adults. Nature, 1970, 225, 959-960.

Page, H.A., Rakita, G., Kaplan, H.K., and Smith, N.B. Another application of the spiral after-effect in the determination of brain damage. J. Consul. Psychol., 1957, 21, 89-91.

Rechtschaffen. A., Wolpert, E.A., Dement, W., Mitchel, S.A., and Fisher, C. Nocturnal sleep of narcoleptics. Electroenceph. Clin. Neurophysiol., 1963, 15, 599-609.

Regellsberger, H. Uber vegetative korrelationen in schlafe des menschen, Z. Ges. Neuro. Psychiat., 1942, 174, 727.

Reite, M.L., and Pegram, G.V. Cortical temperature during paradoxical sleep in the monkey. Electroenceph. Clin. Neurophysiol., 1968, 25, 36-41

Rouse, S.W. Thresholds of beta motion reported by mental defectives. Unpublished Masters Thesis, University of Florida, June 1960.

Ruttenberg , A. The two arousal hypothesis: Reticular formation and limbic system. Psychol. Rev., 1968, 75, 51-80.

Saucer, R.T.. The effect of rate and energy upon the perception of apparent motion. Ph.D. Dissertation, Department of Psychology, University of Florida, 1954.

Saucer, R.T., and Deabler, H.L. Perception of apparent motion in organics and schizophrenics. J. Consult. Psychol., 1956, 20, 385-389.

Scheibel, M.E., and Scheibel, A.B. Periodic sensory nonresponsiveness in reticular neurons. Arch. Ital. Biol., 1965, 103, 300-316.

Snyder, F., and Scott, J. The psychophysiology of sleep. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of psychophysiology. New York: Holt, Rinehart and Winston, 1972.

Sterman, M.B. The Basic Rest-Activity Cycle and sleep: Developmental considerations in man and cats. In C.C. Clemente, D, Purpora, and F. Mayer (Eds.), Sleep and the maturing nervous system. New York: Academic Press, 1972.

Stern, A. The latency of the spiral after effect and after effect as a function of illumination and speed of rotation. Dissertation Abstracts, 1959, 20, 1442.

Strumwasser, F., The demonstration and manipulation of a circadian rhythm in a single neuron. In J. Aschoff (Ed.), Circadian clocks. Amsterdam: North-Holland Publ. Co., 1965.

Taub, J.M., and Berger, R.J. Sleep stage patterns associated with acute shifts in sleep-wakefulness cycle. Electroenceph. Clin. Neurophysiol., 1973, 35, 613-619.

Wada, T. An experimental study of hunger and its relation to activity. Arch. Psychol., 1922, 8, 1-65.

Weitzman, E.D., Fukushima, D., Nogeir, C., Roffwarg, H., Gallagher, T.F., and Hellman, C. Twenty-four hour pattern of the episodic secretion of cortisol in normal subjects. J. Clin. Endocrinol. Metabl.,1971, 33, 14-22.

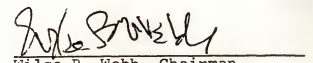
Werner, H., and Thuma, B.D. A deficiency in the perception of apparent motion in children with brain injury. Amer. J. Psychol., 1942, 55, 58-67.

Wilson, S.R. The relationship between measures of cortical alpha activity and measures of apparent motion. Unpublished Masters Thesis, Department of Psychology, University of Florida, January, 1955.

BIOGRAPHICAL SKETCH

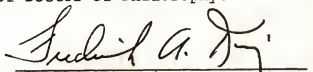
Peretz Lavie was born February 19, 1949 in Petach Tikva, Israel. He obtained his B.A. degree in Psychology and Statistics at Tel-Aviv University, in Israel, and continued his graduate work in Psychology at the same institution. He taught statistics as a junior lecturer, and was a research assistant in the Psychology department. In 1971, he transferred to Florida State University after being granted a scholarship by the International Rotary Foundation and graduated with a master's degree in Psychology in August, 1972. In September, 1972, he entered the graduate school of the University of Florida, and is currently engaged in work leading to the degree of Doctor of Philosophy in Psychology. During his stay at the University of Florida he has been a graduate research assistant to Dr. Wilse B. Webb.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Wilse B. Webb, Chairman
Graduate Research Professor
of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Frederick A. King
Professor of Neuroscience
and Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert L. Isaacson
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

C. Michael Levy
Associate Professor of
Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Edward P. Horne
Associate Professor of
Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mark C. Yang
Assistant Professor of
Statistics

This dissertation was submitted to the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 1974

Dean, Graduate School